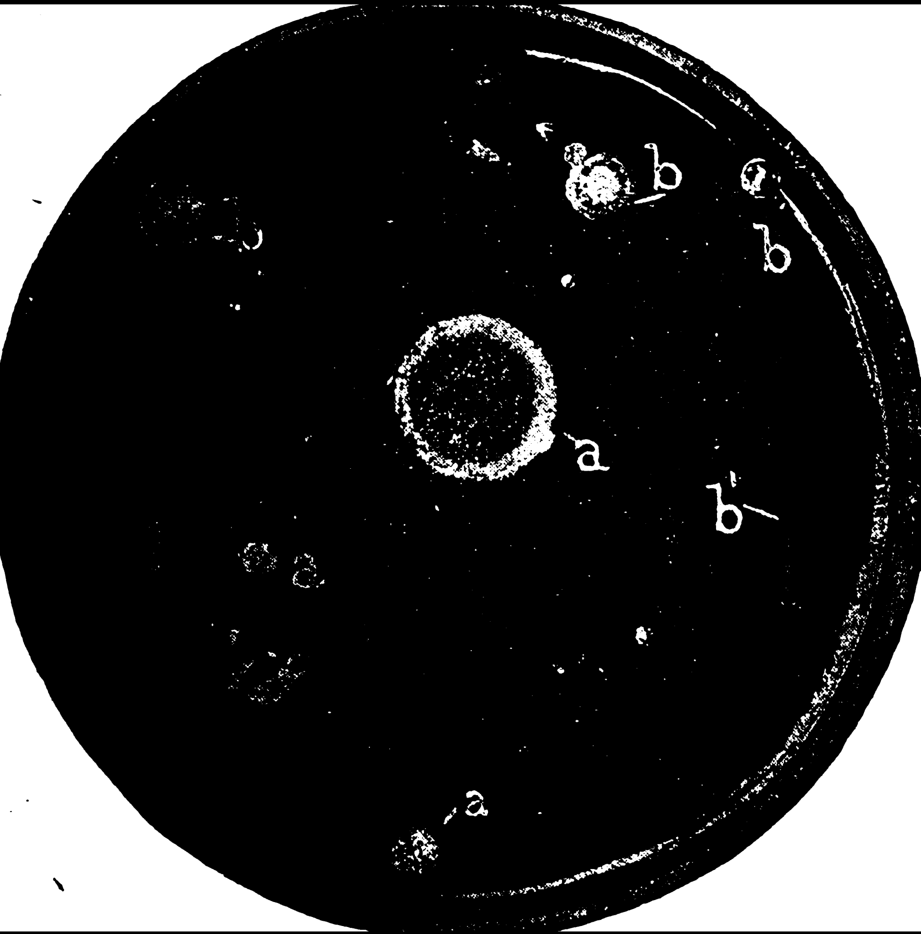
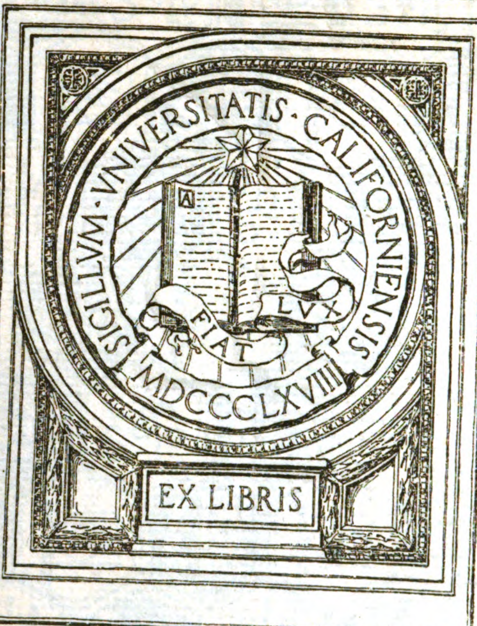


Lessons in practical hygiene for use in schools

Alice Ravenhill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LESSONS IN

PRACTICAL HYGIENE

FOR USE IN SCHOOLS.

BY

ALICE RAVENHILL, F. R. SAN. I.

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WITH PREFACE BY

PROFESSOR M. E. SADLER, M.A.

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PREFACE.

THIS book is the work of a practical teacher and the outcome of strong conviction and of varied experience. Miss Ravenhill is convinced that, by means of a wisely directed education, the community must be permeated by a clearer understanding of the conditions which determine healthy growth and subsequent adult efficiency in national life. With a view to the diffusion of this knowledge, she has long been engaged in training teachers in hygiene. By her lectures and by her personal influence, she has done much to draw public attention to the far-reaching importance of the study to which this book is an introduction.

By the nature of the case, education is for the most part a conservative thing. It is tenacious of precedent, and prone to conventional points of view. Its main business is to link together the successive generations of men and to secure the continuity of their social life. When, therefore, a great change takes place in men's way of thinking about their place and work in the world, there is always, sooner or later, a conflict in educational ideas. New studies assert their claims; old studies defend their place. Eventually, after a long struggle, things come into a new focus and the relative importance attached to the different studies is changed.

At the present time, educational ideas are passing through one of these periods of change. The underlying cause of this change is the scientific movement in modern thought. One result of that movement has been to throw a new emphasis upon the physical side of education. People realize, more vividly than heretofore, the interdependence of mind and body. Their eyes are opened to the fact that unhealthy conditions of living are a drain upon national strength. Thus the word education has insensibly gained a wider meaning. The work done in schools, so far from being the whole of national education, is only a part of it and not in all circumstances the most significant or fruitful part. The chief psychological factors in national education are the influence of law and of customary habit and

thought, and the directive power of public opinion. Nor, even in the case of the children, can the day-school accomplish much of permanent good without the co-operation of the home. Home conditions, school conditions and workshop conditions are inseparably connected parts of one problem. Scholastic matters do not form a distinct group of questions which can be discussed without any close regard to their social context. The perception of this fact makes the task of the educational reformer far less simple than at one time appeared. But though more complex, his task is really more hopeful than before, because it is seen in a truer light, and has lost its old appearance of delusive simplicity. The same widening of view which has extended the educational worker's responsibility, has also affected workers in the other parts of the field of social reform. Just as he feels the dependence of his work on theirs, so they realize the necessary connection between their efforts and his.

A more active health-conscience would prove one of the most powerful agents for the betterment of the conditions of national life. Much has been done during recent years to arouse and inform it. But the chief opportunity of influence lies through the organized teaching of the schools. Step by step the importance of the teaching of hygiene is being recognized by public authorities, central and local. Instruction in the working of some of the simpler laws of health is expressly named as one of the aims of the public elementary school. Provision is made for it in an increasing number of secondary schools for girls. Instruction in it is now required in the case of all students who are being trained for the profession of teacher in elementary and other approved schools. But, though the outlook is thus hopeful, much remains to be done before the teaching of hygiene on practical lines can be regarded as an effective part of our national education. Towards this end, Miss Ravenhill's book will serve a useful purpose.

MICHAEL E. SADLER.

PREFACE TO SECOND EDITION.

The early call for a second edition of this book offers an acceptable opportunity to revise and bring a few of the Notes up to date. Cordial recognition of their much-valued assistance in this connection, is due to Miss Michaelis, M.A., and to Mr. Henry H. L. Smith, B.Sc., (Vict.), whose welcome suggestions and criticisms carry all the weight of long teaching experience, as well as of scientific knowledge and training. Occasion is also afforded for clearing up one or two misapprehensions which have arisen from a failure on my part, perhaps, to give sufficient prominence, in the first instance, to the reasons which would show these to be groundless.

The book is not intended as a manual for pupils of ordinary school age; its scope is too extensive, and some of its contents are too exacting, for the mental pabulum or the manual practice of even sixth-form scholars. It is designed rather to serve as a reservoir of suggestive material to teachers in various types of institutions and schools, from which they can select according to the requirements of their classes in respect of age, scheme of study, or method of application. To students in Training Colleges it is anticipated however, that the book itself will be useful. It has been purposely framed on generous lines, in order to emphasize a side of the subject still too often overlooked, namely, its almost encyclopædic comprehensiveness.

The suggestion has been made that a book of less extensive scope would meet a need in Elementary Schools. To those who have given themselves the trouble to study the contents of the present volume, this proposal seems superfluous. It is a question of selection only. The needs of individual schools and scholars are infinitely varied. The general teacher who has no time, and little opportunity, to pursue the study of Hygiene with all the resources of a Public Library, depends much for the preservation of his true perspective upon the aid, imperfect as it is, of a compendious text-book.

It is also advisable clearly to impress on students of all

ages that the carrying out of these few experimental observations and tests, even under conditions of the greatest care and subsequent to much preliminary training in scientific knowledge and method, will not qualify them to act as analysts, or to pose as experts even in the domestic circle. For this, prolonged, advanced, and specialized study is indispensable, together with conditions of work impossible to secure in a school laboratory. These observations and tests are given a place in the book in order to open the minds of pupils to the scientific principles upon which sanitary precautions or practices and sometimes somewhat irritating, restrictive, legal measures, essential to the public welfare, are based. The ingenuity of common sophistications and the delicacy and skill requisite for their detection also, need constant emphasis. My experience, however, convinces me that, so long as the disinclination to guide conduct by the light of unseen facts persists, the advantages of teaching the tenets of Hygiene by demonstration, and, where possible, by personal experiment and observation, can be scarcely overestimated. The results of this method have been stimulating and beneficial wherever it has been given a fair trial, but, just as much as its practical success depends upon the enthusiasm of the teacher and his power to link laboratory learning with daily life, so does its educational value and moral legitimacy hinge upon the teacher's ability and discretion to utilize visual impressions as a spur to right conduct, while emphasizing the scientific intention with which they are made.

No apology, therefore, is offered for the treatment of part of the subject in what may appear to be a somewhat popular manner. If the necessity for the study of general Hygiene is to be brought home to a considerable section of the public, it seems clear that too strictly a scientific presentation of certain of the more technical portions would tend to discourage such study and to defeat the end in view. The hope that this book may serve as one agent to this end is the sole reason for its publication.

ALICE RAVENHILL.

Nov., 1908.

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PRACTICAL HYGIENE.

INTRODUCTION.

SCIENCE in general has been defined as "accuracy about common things," and educationists increasingly lay stress upon the supreme necessity of not only imparting instruction by means of observation and experiment, but of testing the accuracy of impressions received, by requiring subsequent practical application, in suitable forms, of such instruction, by the scholar. Here is a plea of great weight in favour of the more general introduction of the elements of hygiene into school time-tables; for its study embraces the person, the family, the home, the school buildings, and the familiar surroundings of village or town. These offer materials for the application of each truth imparted; for the exercise of unlimited observation, and for the systematic use of eyes, hands and ears, in testing, experimenting and applying hygienic principles to concrete cases. In fact, no branch of instruction has more intimate relation with, or permits of readier application to, the actualities of life, than that of hygiene. For hygiene has been aptly described as not itself a science, but as the application of a whole group of sciences to the world's needs—a lens through which the experience and knowledge of the human race can be focussed upon the conduct of healthy existence.

From one point of view, and that not the least important, the advantages to be derived from a general practice of hygienic principles are largely economic. Knowledge of these principles should therefore be required as a part of general education, in order that both the home and the community may profit as largely by the teachings of modern science, as have our industries from similar relatively recent discoveries.

Improved health, for instance, means increased individual and collective efficiency, greater productive power, a prolonged

period of working life, diminished rates for the maintenance of the orphan, the sick, or the prematurely disabled, and less expenditure upon the support of general and isolation hospitals.

Now the making of provision for the perfect development of innate individual capacities, for the maintenance of vigorous health, and for the prolongation of human life and efficiency, rests chiefly in the hands of those most immediately concerned. The intelligent promotion and enforcement of sanitary and educational regulations devolve in most instances upon local governing bodies; the responsible work of whose members ought consequently to be based upon sound knowledge of some, at least, of the essential conditions upon which good health depends.

Unfortunately the time is not yet ripe for a knowledge of hygiene to be a required qualification of those who undertake the task of local government or the supervision of measures directed to educational ends; while only a limited proportion of the population realize to-day their individual responsibilities in respect of the application of known hygienic principles to daily life.

The enjoyment of purer air, food, and water, of more wholesome dwellings, and of more rational recreation, depends more upon public opinion and popular habits than upon legal enactments. The reduction of the rate of infantile mortality and the incidence of preventible diseases rests with the people, not with their legislators. Indications are still painfully obvious, as Prof. Huxley pointed out thirty years ago, "of a strong, though perhaps an unavowed and half-conscious, under-current of opinion that the phenomena of life are not only widely different, in their superficial characters and in their practical importance, from other natural events, but that they do not follow in that definite order which characterizes the succession of all other occurrences, and the statement of which we call a law of nature. Hence arises the want of heartiness of belief in the value of knowledge respecting the laws of health and disease, and of the foresight and care to which knowledge is the essential preliminary . . . . and a corresponding carelessness in practice, the results of which are too frequently lamentable."

Meanwhile, the helpless section of the community pays a heavy annual toll of mortality to prevalent ignorance, a large percentage of which is inexcusable. To the national loss represented by the thousands of children who die prematurely must be added the diminished efficiency of the tens of thousands who survive with enfeebled constitutions. These struggle through the working years of life at a level far below the standard of healthful vigour to which they are entitled, but to which, given a fair chance, they could have attained. Recent enquiries and statistics show, with painful clearness, that surviving children born in years of high infant mortality, bear evident traces of the adverse factors responsible for the high death rate. Such "scars" are capable of recognition throughout school life by observers skilled in the detection of visual, aural, and other defects, which register deviations from the normal standard of health and good development.

Intelligent care, too, is necessary in these days to prepare bodies and minds for the high-pressure existence of modern life, and to enable them to retain health and vigour (especially of the nervous system) in an existence so far removed from a state of nature. For, after all, for the purposes of ordinary life, general capacity outweighs unequal though brilliant developments. Every *healthy* child can be made capable, though all children, like all materials, will not take an equal polish. But so long as man remains "the sickest beast alive," a large percentage of human beings will be burdens, and not blessings, to the community.

If these conditions are to be changed, it can only be by the active co-operation of both men and women in the observance of certain measures, often necessarily of a restrictive character, which depend primarily upon intelligent, popular support.

Habits, as the name imports, are truly things which "have us," and observation shows that no one class is more exempt from the grip of habits which make for ill-health, or lower vitality (and thus handicap many otherwise prosperous careers), than it is emancipated from the responsibility of individual participation in the promotion of the national health. "The deepliest-rooted habits of the country," it has been said, "consist

largely of insanitary customs and morbid superstitions, prejudicial to individual development, domestic welfare, communal comfort, or national prestige." The difficulty of uprooting such habits is obvious, as is also the need of encouragement to those upon whom devolves the duty of uprooting them.

Teachers, especially, see the deplorable outcome of the prevalent ignorance of health-preservation, and no class knows more fully the results of such ignorance. They are visible in the form of deficient mental or sense development; of malnutrition, not as a result of "starvation" in the general use of the term, but of improper food; of unsuitable clothing; of diseases caused solely by dirt of skin and hair; of eyes blinded for lack of ordinary care; and of slight ailments almost coaxed into serious illnesses by gross ignorance on the part of a child's natural guardians.

Children have been variously defined as "bundles of possibilities mostly unsolidified," and as "parcels of impulses." It devolves upon parents and guardians to ensure that the process of solidification shall take place under the best conditions, and that the impulses shall be directed along the best lines.

Herbart has well said—"There are three stages through which we must pass: Knowing; Doing; Being. The final object of learning is 'doing,' and before we can act properly we must have properly learned." For which good reason cordial support should be afforded to the active efforts now being made to offer opportunities for the intelligent training of young people in their duty to themselves and to the community, by placing before them a high standard of health possibilities at an age when habits are forming.

The scope of hygiene must be realized by, and its intelligent practice required of the whole nation. If house-keeping and the right rearing of children be woman's privilege, the right keeping of towns and villages devolves chiefly upon man, into whose hands are confided the planning and structure of dwellings; the provision of water and direction of drainage systems, the production, protection, and distribution of foods, and the control of most measures promoted in the cause of sanitation. It is a

common custom to refer to the tenets of hygiene as binding upon the poorer section only of the community, in which almost every difficulty of practice is enhanced by ignorance and environment; but what responsibility and power for good rest with land-owners and large employers of labour; what opportunities for effecting desirable improvements in the management of children and of homes present themselves to women of means and leisure!

Experience, unfortunately, compels the confession that many parents ignore, or neglect, their obligations; so that the duty perforce devolves, for the present generation at least, upon the teaching profession.

If one object of our educational system be the preparation of children for the wise conduct of their lives, it behoves the great army of teachers to drill their millions of recruits into obedience to the primary laws of practical hygiene, until a diminished rate of mortality, brighter skies, cleaner cities, purer water-supplies, healthier homes, and better proportioned figures and happier faces replace the gloom, dirt, dilapidations, deformities, and largely preventible sicknesses which now so injuriously affect life in town and country.

Teachers should, therefore, aim not only at surrounding children with improved conditions, but also at making use of the child's earliest instincts to touch, taste, and handle the things about him, and thus to interest him in sound reasons for the right use and care of the safeguards to health which are now found in almost every house (though not always intelligently used). Habits formed thus early cling through life, and influence every subsequent thought and action.

The subject, however, must be treated practically; illustrations must be drawn from, and applications made to, the children's own experience and immediate surroundings; for which purpose the school, its system of ventilation, its water-supply and fittings, etc., have been officially* and wisely suggested as objects upon which to demonstrate theories otherwise difficult for young minds to materialize.

* "*Suggestions for the Consideration of Teachers*," pp. 86 to 91, and Appendix II. (*Wyman & Sons, London, 1905, Price 8d.*

Moreover, the lessons must not be dull, nor lack vitality; and technical terms, though useful in their place, must not be allowed to obscure every-day truisms. The treatment must be elastic, adapted not only to different ages and to varied requirements, but also to the equally varied duties, interests, and responsibilities of children and young people in homes, schools, and colleges of different grades. In one class of school the domestic aspect of the subject must be most emphasized, in another the economic, in others the social, the commercial, or the personal must be presented with more prominence.

Of course, the amount of theoretical hygiene acquired by such teaching could only suffice as an introduction to the subject. But, if the right method of instilling these elementary truths be adopted, it will excite that spirit of enquiry which Professor Michael Foster says is one aim of teaching, and which opens minds to intelligent conviction; so that future actions would be insensibly influenced for good by these lessons. If the child be but trained to attach due importance to the laws of health, though his knowledge of theories be limited, he will nevertheless be prepared in later life to estimate at their right value the further developments and his own responsibility in respect of the science of hygiene.

Considerable attention is now devoted during school life to a study of nature's laws in elementary physics, chemistry, physiography, and elementary biology, though too little energy has hitherto been concentrated on the direct application of these sciences to the health of mankind. This is the more remarkable, in view of the intimate connection between sane, self-controlled, evenly-balanced minds and well-developed, healthful, vigorous bodies. Habits directed towards the attainment of the former are generally inculcated in childhood, while the tardy efforts made to promote a similarly desirable physical condition are permitted to be neutralized by tacitly accepted prejudices and ignorant habits. Broad principles of morality are inculcated from the cradle; the importance of acquiring sound habits of truthfulness, honour and courage are amply recognized; but no adequate scheme has yet been generally devised or adopted for

the acquirement of a sanitary conscience, or for training a sense of duty to the physical well-being of self or neighbours.

The scheme of school studies should constitute an organic whole, therefore instruction upon the right conduct of life should be intimately and logically linked with the whole school curriculum, which has for its objects "to form and strengthen character and to develop intelligence; to train children in habits of observation and of clear reasoning; to arouse in them a living interest in the ideals and achievements of mankind; to secure healthy development of their bodies by appropriate physical exercises and organized games, and by instruction in the working of some of the simpler laws of health."*

Given these objects, plus the subjects comprised in the timetable of either primary or secondary schools, and a child could gain considerable information with regard to the principles and practices of hygiene by correlational methods during his ordinary school course.

Thus, by means of nature study, he would, as has been pointed out by Miss Hoskyns-Abrahall, "know accurately, though, of course, in outline, the main structure of the bodies of several different groups of animals and plants, and the functions of their different organs; so that he would understand what is meant by circulation, respiration, nutrition, etc., and would be trained to observe what hindered and what furthered these functions."

His observations would extend to the simpler effects of nutrition and environment upon the well-being of plants and animals—at least, so far as food and water, air and sunlight, cleanliness, shelter, and overcrowding are concerned. The theories and laws of physics and chemistry would find apt illustrations and practical applications in respect of problems of ventilation, heating and lighting; of domestic conveniences; of water supply and drainage; of food production, distribution, preparation and preservation. Physical training and games would, with very little theoretical assistance, impress the results

* Introduction to the "*Code of Regulations for Elementary Schools*," 1906-7, issued by the Board of Education.

of exercise and recreation on mind and body. History would develop a more human interest when it supplies reasons for the nomadic habits associated with early stages of civilization; or when it proves a source of information on the modes of existence and domestic customs of the past; *e.g.*, when the life in school and home of the child—Egyptian, Hebrew, Greek, or Roman—can be compared with twentieth century habits. The plagues and famines of mediæval times may be turned to account to preach cleanliness and forethought to-day; while to trace the gradual evolution of the familiar conveniences of a modern home will inspire many a girl to consult the pages of her history with an interest reflected in her brother, as he seeks the causes of modern commercial and industrial developments. Geography opens up a wide field for study in respect of the influence of climate and environment on food, industries and population; leading on to consideration of water-supply, soils, and means of subsistence in their bearing upon national life, its persistence and prosperity. Arithmetic may be legitimately pressed into the same service. Young intellects can be exercised with absolute propriety upon really useful, living problems, concerned, for instance, with the size of cities and houses, their water-supply and other sanitary measures, their market requirements and provision of open spaces per head. Children are usually interested in all local arrangements of these and similar characters; here is the opportunity for making this interest intelligent and practical. There will thus be a constant, though infinitely varied, reiteration of fundamental hygienic principles and facts throughout school life, which will serve to impress them indelibly, yet without weariness, upon the plastic minds of the children.

The study of hygiene is usually limited, as has been well expressed by a Committee of the American Academy of Medicine, "to the first of the two primary laws of life, perfection of the individual, owing to certain practical difficulties in the way of teaching the second, which is concerned with the transmission of life." But the more general introduction of elementary biology as a school subject removes many difficulties from the path of the competent teacher, for children can thus be intro-

duced, by the comparative method, to the general principles of growth, development and reproduction. In the higher animals, some of the facts of sex and reproduction are indeed so conspicuous as to be accepted with perfect simplicity from sheer familiarity. The similarity between life-processes in the animal and vegetable worlds affords numerous opportunities for helpful comparisons to be instituted, or tactful applications to be suggested.

One clever and successful teacher builds a two years' course of study, continued from the simplest forms of plant life up to complex animals upon the text "The two objects of every living thing are to perfect itself and to reproduce itself." In the processes of this "perfecting," human and personal resemblances are constantly traced.

For a study of cell life, yeast cells (with microscopes) are used, and the children draw the cell-reproduction seen. They first observe and then draw (with the teacher's help), *spirogyra* and reproduction by conjugation of like cells; *vaucheria* and conjugation of unlike cells; all leading to the terms "mother plant" and "father plant," which are continued through the two years, with allied terms in plant and animal "families." These processes are traced through higher plant forms—spores, seeds, flowers, pollination by natural and artificial methods—by the children themselves, under the teacher's guidance. The upper classes utilize insects, birds, white mice, tadpoles, etc., kept in vivariums, cages and aquariums; thus showing various forms of development daily. Economic and sociological as well as physiological and hygienic principles are also taught, so that the children's eyes are opened to a conception of the close relation which exists between individual efficiency and national prosperity. It only remains for parents and teachers to see that the knowledge thus almost insensibly acquired concerning these primary laws of life shall be directed to healthy and useful ends.

For desirable as it is that parents should relieve teachers of the chief part of such introduction to the deeper things of life, it is nevertheless advantageous to employ the resources of a school to explain much that is otherwise very difficult of explanation;

while nothing but good can result from the weaving of a firm connecting web between home life and school studies.

If more direct methods be desired for giving instruction in hygiene, three or four are open to the teacher, which may be described as the (1) Conversational; (2) Biological; (3) Theoretical; (4) Superstructural.

(1) The conversational is essentially the method to be pursued for the first three years, or even longer, of school life, if only because it relieves the tension of sustained attention, which otherwise frequently interferes with the enjoyment of a subject which should prove very attractive; and also because it permits of opportunities to volunteer those scraps of personal information, or that comparison of experiences, at once so dear to the childish heart, and so profitable as pegs upon which to hang precepts. A young child's mind deals with concrete and isolated facts rather than with abstractions and the relations of facts; consequently teaching by this method could be most profitably given in these early years.

The home may be taken as the pivot around which both family and civic life revolve. Starting with the idea of this home as the cosy shelter for warmth, rest and happiness, attention could be directed year by year to the essentials of such a healthy, happy house; to its necessities, comforts and conveniences, such as light, air, space and cleanliness; later to its aspect, surroundings, cost, repairs and fittings; while a slight outline of the protection afforded to all by our Public Health Laws might be introduced towards the end of school life.

Cleanliness and comfort in the person, home and community could be incidentally discussed, and would include consideration of food and water. A necessary supplement would be some teaching on the respective values and importance of judicious rest, work, and play. For older children the series might conclude with lessons on the care of the person, preservation of health, and the health of the community.

Each of these points would be gradually developed along parallel lines each school year, the parts eventually making a fairly complete whole. The conversations and selected illustra-

tions should be bright and attractive, each talk being illustrated by homely facts, as well as, so far as possible, by actual objects, pictures, and models; though, I think it is advisable to confine these to wood, card, earthenware or metal models of houses, their equipment, furniture and sanitary appliances. Papier mâché models of the human body or its parts, perfect as these may be for more advanced students of physiology, are liable not only to shock or disgust young children, but inevitably give them false impressions of the delicate tissues they are designed to represent.

(2) The biological method has been employed with the greatest success of any hitherto tested in the United States, especially in the High Schools, where it is pursued by boys and girls from about 14 to 18 years of age. The course in elementary practical biology usually coincides with a practical study of physics and chemistry, and leads on, with no perceptible break or change of method, to human physiology, which is thus approached from the general, not personal, standpoint; a mode of undoubted value at an age period when stimulus to any form of introspection is to be carefully avoided, yet when natural curiosity is active and should be truthfully and gradually satisfied.

Observations upon the structure, organic systems and functions of the human body can be conducted as impersonally as are those carried out in the case of plants and lower animals. Comparisons can be encouraged between the various means employed by Nature for fulfilling the vital and other functions, in order to test and revive knowledge previously acquired and to quicken interest in man's physical nature. Human dependence upon nutrition and environment being thus clearly demonstrated, a new light is thrown upon civic responsibilities and domestic duties; a fact to which the steady growth, in the United States, of numbers in attendance at College and University Courses, on "Sanitary and Social Science" and on "Household Economics" bears valuable witness.

Leaving the third method entirely out of account, for its failure is generally recognized, the following series of demonstrations and experiments is presented as suitable for the use of

pupils, either as a supplement to their work in nature study or in elementary biology, or as a collection of suggestive and helpful hints to teachers who prefer to employ the fourth or superstructural method. Here the aim is to secure some connection between lessons and life by correlational links until the last few months of the school career, and then to concentrate attention for the short remaining time upon the study of man's physical nature, and the conditions of life to which he has more or less to adjust himself.

These exercises are based upon experience gained personally in the conduct of classes in hygiene, where, from the inception, effort was directed towards stimulating the student to a vivid interest in the characteristics and requirements of life; to admire afresh the beauty and adaptability of the human body; to trace for himself the law of cause and effect in Nature; to observe for himself the provision made for, and necessary to, the development of a healthy, symmetrical, harmonious existence; and to realize for himself the power over conditions, and the control over circumstances, which come from observations so made and from knowledge so acquired. The results of these tentative and imperfect efforts far exceeded expectations. The adoption of the method by other teachers, in other districts, with widely varied types of students, has achieved similar success; though all thoroughly realize the elementary and fragmentary character of the course of study, and the great possibilities for its future enlargement and elaboration.

Each season brings into well-deserved prominence the fact that others are working for the same ends along parallel lines. It is with no thought, therefore, of superseding their recorded experience that these pages are published. They appear in response to repeated requests to place at the service of the many what has proved helpful to the few; to embody the tested experience of several years in a more permanent form; and to secure the valuable assistance, for future editions, of those whose criticisms and suggestions will be elicited by their publication.

The exercises are very simple; they have been studiously framed to involve small expense, so as to be possible of perform-

ance by pupils in an ordinary class-room, and to encourage observation upon matters so familiar as to be often easily overlooked. More advanced work can be easily introduced, as, for instance, the microscopic study of the tissues or of food stuffs, for which excellent text-books are available. The whole object of this little book is to encourage, first-hand, individual observations and applications, in order to rear a race of more intelligent citizens and more responsible parents, and to link with the most familiar objects and facts the significance they carry in the right conduct of daily life.

The actual material here presented has been gradually collected from a very wide range of sources over a considerable number of years. Many of the demonstrations have been devised to meet special points; others were suggested by friends, or have been adapted from sources unfortunately far too numerous to detail, and consequently impossible of individual acknowledgement.

Special mention must, however, be made of the invaluable assistance received in verification of tests and in useful suggestions from Miss Hoskyns-Abrahall, M.A., Miss E. M. Morris, Inspector and Teacher of Hygiene, W.R.C.C., and Mr. Walter C. Tyndale. Also acknowledgement must be publicly made to Professor Colton, Professor Leonard Hill, Miss Bertha Brown, S.B. (Hyannis, Massachusetts), and Mr. J. E. Peabody, A.M. (Peter Cooper Hill School, New York City), for the assistance and stimulus derived from the work they have carried on in the same field.

ALICE RAVENHILL.

PART I.

I.—REQUIREMENTS OF LIFE.

It is well from the first to impress two facts on young minds, the first, that *Hygiene*, or the *Science and Art of Preserving and Promoting Health*, applies to, and has long been practised in connection with, all forms of life—vegetable and animal; the second, that in consequence of the great similarity in their requirements for healthy existence, observations on plants and animals assist man to a knowledge of many of his own needs in this connection.

For school purposes, profitable and interesting observations can, without expense, be carried out by the children themselves with seeds and plants. Though the applications made must naturally be influenced by the age of the pupils, yet the attention of young children can be aroused to a most satisfactory degree where this method is pursued.

As a useful and interesting preliminary introduction, therefore, to any course of lessons in the general principles of hygiene, it is advisable to direct attention in the simplest way to those elementary phenomena of life, which are associated with constant changes of a chemical character (technically termed *metabolism*), including the processes of assimilation and excretion; to the fundamental facts of heredity, adaptability, growth, and reproduction; to one or two of the most obvious evidences of the transformation of energy which occur in life-processes—for example, movement and heat production; to the dependence of healthy existence upon food and surroundings, as well as to the inability of life to develop at all unless certain conditions be fulfilled.

To this end, it is well to provide small pots filled with earth or sand, and a supply of broad beans, Indian corn or other quickly-growing seeds. Each member of the class should be directed to plant one or more seeds in one of these pots, and

should also be made responsible for a certain number of pots, with orders to care for the seeds as seems best during two or three weeks, according to the time of year, keeping a record of the means employed to secure growth.

On a fixed date the seedlings should be brought for inspection. Some of the plantlets should be up-rooted and carefully compared as regards general development, symmetrical growth, and signs of good or poor nutrition. Very marked differences will be apparent, the result of varying conditions of temperature, moisture, air, light, soil, space and modes of sowing the seeds. Observations, deductions and applications can be made according to the age of the class. With quite young children, comparisons can be instituted with the needs of pet animals and the provision at home for family requirements, warmth and shelter, food and drink, &c., and their attention can be directed to certain obvious results of intelligent care or ignorant neglect.

Older and more advanced pupils can be led to note the facts that each species of seed develops after its kind (*heredity*); that in addition to a general resemblance each seed possesses some individual characteristics (*idiosyncracy*); that all make more or less successful efforts to adapt themselves to their surroundings (*adaptability*) and, in turn, are *modified* by their environment; that nutrition is supplied in a variety of forms; that *growth* is influenced by numerous factors; and, finally, the obvious necessity of some provision for continuing or perpetuating the species, which function is described as *reproduction*.

Comparisons can be instituted between the appearance of beans raised under various conditions and that of overcrowding, of insufficient light, of impure air or of improper food, among other forms of life, notably human beings; while attention should be directed to the unnecessary expenditure of energy, usually accompanied by stunted growth, which results from unfavourable conditions in early life. These points can all be well illustrated by bean plantlets which have been deprived of sufficient light and air; insufficiently supplied with water or soil; sown too thickly or in positions which do not permit the normal growth of *plumule* and *radicle*. Where some conditions are favourable

and others adverse, numerous seeds will succeed in achieving their end of growth and development, but at what output of energy will be seen by comparison with a well-grown plantlet raised amid an ideal environment. In many cases the struggle will probably prove too severe and some seeds will die.

II.—PHENOMENA OF LIFE.

Examination of tests of seeds for evidences of life. Conditions essential to germination (moisture, warmth, air).

DIRECTIONS.

STARCH CONTROL TEST.—*Place a small quantity of cool starch solution in a test tube, and add a few drops of iodine solution. The dark violet colour shows the presence of starch; a reaction invariably obtained where unaltered starch is present.*

I.—Examination and tests of Seeds for evidences of life.

MATERIALS: *Broad beans; Indian corn; peas; castor-oil beans; water; vaseline; starch;* 10 *c.c. iodine solution.*

APPARATUS: *Small knife;* 3 *wide-mouthed bottles; test tube;* 3 *corks, or glass plates; taper.*

(*A*) The *outward* appearance of the seeds selected, preferably peas and broad beans (*Fig.* 1), should be observed under the following conditions:

(*a*) Dry.

(*b*) Soaked for three hours.

(*c*) Soaked for 48 hours.

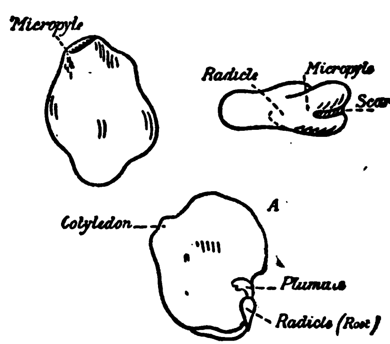

FIG. 1.

NOTE.—(*a*) Hard, dry, crinkled.
(*b*) Outer covering (*testa*) rather softer.
(*c*) Smooth, full and elastic to the touch.

(*B*) Split open the seeds (*a*), (*b*), (*c*), and note further evidences of developing life.

NOTE.—(*a*) Hard, dry.
(*b*) Softening near outer covering.
(*c*) Whole seed softened and signs of germination.

(*C*) Paint a weak solution of iodine over the inner surfaces of the beans split open in (*A*) and (*B*), observing carefully the resulting changes of colour.

NOTE.—(*a*) The iodine changes colour by contact with the stored-up food material (*endosperm*) present in the form of starch.

(*b*) The iodine remains brown near the germinating *plumule*, showing where the nutritive changes are active, and that the starch is undergoing alterations.

This affords an opportunity for (1) introducing some first simple ideas of the metabolic changes which characterize active as distinct from dormant life; (2) directing attention to, and collecting observations upon, the multiple devices found in Nature for securing a supply of nutrition for immature plants and animals during the early stages of their development.

If castor-oil beans are employed, a small piece of the *endosperm* should be warmed in a test tube of water, when evidence of the presence of oil will enable reference to be made to a second important food principle, *viz.*, *fat*. It should be shown that this reserve store of food material (which in peas, beans, &c., contains *proteid* matter) is insoluble in water; a protective measure on the part of Nature, as otherwise it might be washed out of the seed, and starvation would result.

(*D*) Take some seeds of Indian corn, dry and dormant and in various stages of germination and growth. Split them open and compare the appearance.

NOTE.—Where the seedling has been growing some days, the seed coat is darkened and almost hollow, the contained provision being nearly exhausted.

(*E*) Take three wide-mouthed bottles (*a*), (*b*), (*c*); half fill (*a*) and (*b*) with dry beans; leave (*c*) empty; to (*b*) add a small quantity of water.

Test the air in each bottle with a lighted taper; close the three bottles tightly with corks, or with glass plates,

sealing the edges with vaseline. After 24 hours, test the character of the air in the bottles as before, and compare the results.

NOTE.—Care must be exercised that the significance of this simple test for the presence of excess of carbon dioxide in the air is understood by the class. In this instance the increase which is observed is the product of the germinating process in (*b*). It affords a further illustration of metabolic activity wherever active life is present.

II.—**Conditions essential to Germination** (*i.e.*, to the awakening of dormant life).

MATERIALS: 200 *grams oats or peas;* 200 *grams garden soil;* ½-*cake compressed yeast;* 28 *grams brown sugar or treacle;* 2 *sheets blotting-paper; water.*

APPARATUS: 2 *bell-jars;* 2 *small plates;* 2 *small pots;* 2 *glass jars;* 5 *wide-mouthed bottles or jars; test tubes;* 1 *beaker;* 2 *corks or glass-plates; thermometer; Bunsen burner; retort stand.*

(*A*) *Moisture.* Take two bell-jars (*a*) and (*b*).

Place a handful of oats, peas, or other seeds in a dish under each jar; set aside under similar conditions of warmth (about 20° C. or 68° F.), and darkness, but moisten the seeds under (*b*) occasionally. Compare the results after three or four days. *Or*, fill two small pots (*c*) and (*d*) with stiff, dry soil. Plant beans or peas in each in the ordinary way, and place the pots as above, but side by side, for comparison. Water (*d*) from time to time, so that the soil is moist. Leave (*c*) untouched. Compare the results on the seeds after a few days.

(*B*) *Warmth.* Take two glass jars (*a*) and (*b*).

(1) In each place a handful of selected seeds, previously soaked in water.

Place (*a*) in a warm, even temperature, about 20°C. (or 68°F.).

Place (*b*) near a refrigerator or in a cold cellar.

Watch the results during a period of three weeks; being

careful to exclude the light and to keep the seeds well moistened in each case.

(2) Mix well about a quarter of a cake of compressed yeast with 25 c.c. (1 ounce) of water. Add this to 250 c.c. (½ pint) of water in which 28 grams (1 ounce) of coarse brown sugar, or preferably of treacle, have been dissolved.

Take three wide-mouthed bottles (*a*), (*b*), (*c*), place in each an equal quantity of the mixture, and cork loosely.

Place (*a*) in a temperature of about 30° to 35° C. (or 86° to 95° F.).

Place (*b*) in a vessel of very cold water.

Keep (*c*) at a temperature of about 15° C. (or 59° F.).

At the end of several hours examine the bottles, and note carefully any evidences of "working" in the mixture, *i.e.*, of active life in the dormant yeast cells.

(3) Take two test tubes (*a*) and (*b*). Place in (*a*) twelve peas previously soaked for 24 hours. Place in (*b*) twelve dry peas.

Stand both test tubes in a beaker of water, and raise the temperature to 65° C. (or 149° F.) for twenty minutes; then cool.

Prepare two sheets of moist blotting paper, place the contents of (*a*) and (*b*) between the folds of separate sheets. Keep moist, and count in a few days the number of germinating peas on each sheet.

NOTE.—The effects of the high temperature in each case serves to illustrate *two* useful facts:—

(1) That certain conditions must be observed in order to devolop active life; temperature must be regulated and maintained at a point suitable to the subject.

(2) That the supply of one factor among many is insufficient for the maintenance of normal life; all essentials must be judiciously provided; *e.g.*, moisture may actually be a source of danger, as in the soaked peas, when temperature is at fault; so food is insufficient to protect from deterioration in human beings if cleanliness, sleep, or other factors be absent.

(*C*) *Air.* Take two wide-mouthed bottles or glass jars (*a*) and (*b*). Place a small quantity of seeds in each, covering them with water to the depth of an inch or so. Cork (*a*) tightly, or cover closely with a greased glass plate.

Set aside as directed in (*A*), and compare the character of the germination in each case.

NOTE.—It will be apparent that *three* factors are essential to the process of vigorous germination. Moisture in moderation, heat of a given degree, and air. If any of the three be absent germination may take place, it is true, but only in a weak, unsatisfactory manner. Conditions of an analogous nature exist throughout the organic world with respect to the development of every form of life, and the above illustrations serve as the basis for observations of a more or less advanced character, according to the age, social status, and intelligence of the pupils.

Attention can be drawn to the fact that all manifestations of life can be classified under one of two kinds of changes. A change is either *physical* or *chemical*; it is a change either of place or of composition. Such changes are conspicuous in the inorganic as well as in the organic world, of which the following series of examples affords illustration:—Unsupported bodies fall to the ground; water evaporates; dew forms; coal is mined, used as fuel, burned; plants blossom; trees grow; salt dissolves in water; gunpowder explodes; grape juice ferments; iron rusts or melts; water boils or freezes; bananas decay; strawberries ripen; animals breathe air, part of which unites with the blood, this circulates and renews the tissues of the body; animals feel; men think; excitement quickens the pulse; food is digested.

These illustrations, to which almost numberless additions can be made, should be classified as:—

Inorganic changes.

Physical. Chemical.

Organic changes.

Physical. Chemical.

III.—CHARACTERISTICS OF LIFE.

Metabolism (absorption, excretion). Respiration. Irritability (sensation). Energy. Movement. Heredity. Growth. Reproduction. Adaptability. Periodicity.

DIRECTIONS.

To make Nutrient Solution.—*Water*, 1,000 *c.c.*; *Potassium Nitrate*, 1·0 *gram*; *Sodium Chloride*, 0·5 *gram*; *Calcium Sulphate*, 0·5 *gram*; *Magnesium Sulphate*, 0·5 *gram*; *Calcium Phosphate*, 0·5 *gram*; *Ferrous Sulphate*, 0·005 *gram*.

To make Egg Albumin Solution.—*Water*, 100 *c.c.*; *White of Egg*.

Mix the white of egg with the water. This is more rapidly and effectually accomplished if the viscid mass be first snipped in all directions with a pair of sharp scissors. This method is preferable to "whisking," as no air bubbles are formed. Filter, and set the filtrate aside for use.

I.—Observations upon Metabolism.

Materials: *Beans and peas; vaseline; fine string; water; treacle; compressed yeast; taper.*

Apparatus: *Test tubes; 2 glass bowls; corks; balance.*

(*A*) 1. *Absorption.* Compare soaked and dry beans—(*a*) as to size; (*b*) as to shape.

If the moist bean be sharply squeezed, signs of a special part (the *micropyle* or *little gate*), being concerned in the absorption of nutrition can be detected; air and water exude as froth.

Take 12 dry beans. Weigh and record the weight. Cover the micropyle of 6 beans with vaseline; weigh again. Soak all in water for 48 hours. Compare, in each case, the results which are visible in external and internal appearance and in weight.

Note.—"*Phenomena of Life*" I. (*C*) should be repeated, in order to connect the idea of the changes observable in the *endosperm* with the chemical processes associated with nutrition. Opportunity will also be afforded for introducing the idea that each function in the higher forms of life is associated with an organ specially adapted for its due performance, as well as for pointing out the advantages which accrue from the differentiation of parts in an organism.

(*B*) 2. Half fill a very thin test tube with peas; fill up with water, and tie in a cork securely; examine after 24 hours.

Note.—The peas will become wrinkled, then smooth as the process of nutrition proceeds, finally the tube will burst as germination progresses. If the swollen peas be split and compared with dried peas, clear evidence of metabolic changes will be observed.

(*C*) *Excretion.* Half fill two small glass bowls with a mixture of treacle and tepid water, marking the level to which this reaches on the outside of each bowl with a strip of stamp (or gummed) paper.

Take two test tubes (*a*) and (*b*). Hold a lighted taper to the mouth of each, and observe whether it continues to burn; then fill both tubes with a mixture similar to that in the bowls, but add a small quantity of yeast to (*a*). Invert one test tube into each bowl, and set aside for 24 hours at a temperature of 24° to 30°C. (75° to 86°F.) Upon examination (*a*) will be found partially or perhaps entirely empty.

Then proceed as follows :—

(1) Examine the mixture in the bowl to see if its level has been affected by the loss of its contents out of (*a*).

(2) Withdraw (*a*) from the bowl, hold a burning taper to its mouth, and compare the immediate result with those observed in Air II. (*G*) (*b*), and IV. (*A*) (*a*).

(3) Pour 5 c.c. lime-water into (*a*); shake, and compare the milky solution formed with the results obtained in V. and in Air III. (*A*) (*d*), and IV. (*A*) (*a*), (*b*), (*c*).

Repeat the examination with (*b*), and compare results in the two cases.

Note.—The yeast plants in (*a*) are quickened into active growth by the appropriate nutriment and temperature supplied. The metabolic processes associated with their energetic activity (usually spoken of as *fermentation* or the "working" of yeast), result in the generation of carbon dioxide gas, an excretory product, formed in such quantity as to displace the mixture in the test tube. Clear evidence of the nature of this excretion, *viz.*, that it is carbon dioxide, is afforded by the tests subsequently applied.

The addition of a little flour to the mixture of treacle and water contributes advantageously to the success of the experiment.

II.—Absorption and Circulation.

Materials: *White pink; sweet pea; Japanese anemone, or snowdrop;* 10 *c.c. red ink.*

Apparatus: *Test tube.*

Immerse the stalk of a white blossom, *e.g.*, white pink, sweet-pea, Japanese anemone, or snowdrop, in a vessel of red ink for half-an-hour, and keep under observation. Notice the gradual circulation of the fluid through the petals.

NOTE.—The process can be watched in any blossom or leaf, but it is more easily and quickly observable in a succulent white flower. The absorption and circulation of nourishment throughout an organism is thus illustrated.

III.—Diffusion.

MATERIALS: *Potatoes; beetroot; grapes; raisins; egg;* 500 *c.c.* (1 *pint*), 5% *solution common salt; artificial parchment, or animal membrane; stamp paper; water.*

APPARATUS: 2 *flat glass dishes; Bunsen burner; wide glass tube, or thistle funnel; beaker.*

(*A*) Take a fresh potato or beetroot and cut off several slices, each measuring about 5 cm. × 3 cm. × 2½ cm. (2 in. × 1¼ in. × 1 in.). Examine them as to consistency, firmness, pliability, etc.

Prepare two flat glass dishes (*a*) and (*b*). Fill (*a*) with a 5 % solution of common salt, and immerse in it two or three slices of potato or beetroot. Fill (*b*) with fresh water, and immerse a similar number of slices. Examine the contents of each dish after half-an-hour. (*c*) Replace the salt solution in (*a*) with fresh water, again immerse the slices of potato or beetroot; leave for one hour. Compare the results in each case.

NOTE.—(*a*) Flaccid and limp; (*b*) Firm and plump; (*c*) Firm and plump.

To secure intelligent comprehension of the metabolic process which this experiment is designed to illustrate, it will be necessary to explain the cellular structure of organic matter, and the fact that the gaseous, fluid, or semi-fluid substances contained within these living cells diffuse through the delicate protoplasm of which the cells are chiefly composed, an exchange taking place between these semi-fluid or gaseous substances and the medium in which the cells are placed; in this case, water and salt solution. Physiologists have not yet been able to discover the exact details of these complex changes, to which the technical term *osmosis* is applied, though it is well known that they play a prominent

part in the functions of the human body; the principle can, however, be observed in vegetable cells, as in the case of those which compose the potato or beetroot.

The fact that gases are exchanged in the lungs by diffusion is familiar, but it is less generally known that liquids diffuse in animal bodies according to the same laws, though more slowly and with more restricted miscibility. Nevertheless, it is by this means that food substances, after solution in the alimentary canal, pass through the blood into the various tissues. The rate of diffusion varies according to the specific nature of the gases and liquids, and probably also according to the nature of the protoplasm of the cells concerned.

The water used in this experiment contains few substances in solution, and it passes readily in the direction of the denser solution of salts with which the potato or beetroot cells are filled; the opposite condition obtains when these are placed in strong salt solution. It is important to impress, from the first, the fact that these cell-membranes are *living* structures, which, by their activity, enable a plant, for instance, to retain the water which it has "pulled" into its cells, and thus prevent fluids from flowing out as fast as they are absorbed. The derivation of the word *osmosis** explains the significance of the process as being one of "impulsion" *towards* the stronger by the weaker. Many membranes are not permeable to all substances, but exercise a *selective action* and entirely prevent the passage of one substance, while allowing that of another to take place freely.

To illustrate the point that this process of dialysis by osmosis depends for its full efficiency on the work of living tissues, direct the pupils to boil some slices of fresh potato or beetroot in water, and then subject them to the tests in III. (*A*). It will be found that the high temperature has killed these active, living membranes, and the protoplasm too, so that the cell-contents filter through the cell-walls into the surrounding water.

A grape affords a useful rough illustration of a typical vegetable cell, the skin, pulp and seed being compared respectively with the outer membrane, usually present, the cell-contents and nucleus.

Animal cells frequently have no confining outer membrane, though it is present in the case of the yolk of an egg, which thus offers a further illustration of typical cell-structure, useful until pupils can gain first-hand acquaintance, from work with a microscope, with the subject of cellular-structure and cell-characteristics. It is essential

* Greek *ōsmos*, a pushing influence, from *ōthein*, to thrust, push, impel. The impulse or tendency which causes the diffusion of fluids through membranes.

to impress the minute size of ordinary tissue-cells, of which from 3,000 to 5,000 would only measure one inch. Groups of cells may be compared to small, thin-walled boxes, or comparison may be instituted with the structure of a honey-comb, which latter enables the fact to be introduced of the influence of pressure, function, etc., upon the form and work of different cells.

(*B*) Securely close the end of a wide glass tube, or a thistle funnel (*Fig.* 2), with artificial parchment or animal membrane. Half fill it with pure water, and suspend it in a beaker containing a strong solution of common salt. Mark the height of the liquid in each case with a strip of stamp paper affixed to the outside.*

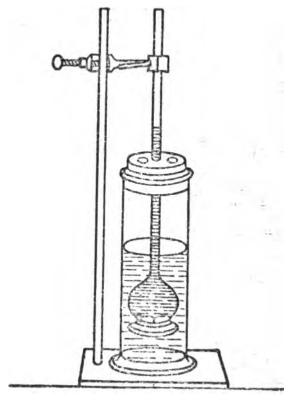

FIG. 2.

Examine the fluids by eye and taste, after two hours, for any evidence of changes which may have occurred.

NOTE.—This experiment illustrates the means known as *osmotic*, by which the process of dialysis is effected, and is designed to throw light on the corresponding, but infinitely more complex and coincidently inexplicable, osmotic processes by which the living tissues of the human body derive their nourishment from, and diffuse their waste products into, the lymph and blood or the air-cells of the lungs.

The salt will diffuse through the membrane into the inner tube, thus illustrating, roughly, the complex process of the taking in of nutriment, in the form of gaseous and dissolved substances, by a living cell, of which the contents possess the property of mixing with food-stuffs for which they have a chemical affinity.

The cell-membrane, if such be present, is represented by the membrane which closes the cylinder; the pure water represents the cell-contents; the strong salt solution represents the substances to be absorbed. These, if they are to be absorbed, must be diffusible. The living substance, how-

* This arrangement is sometimes called a *dialyzer*, though the description is considered inaccurate by many scientists. It is, however, thus referred to on pp. 166, 188 & 302.

C

ever, does not, in its turn, pass *out* of the cell, since the proteid matter (colloid* in character) which enters into its composition, contain characteristic molecules structurally incapable of passing through the excessively fine pores of the membrane, which, however, affords free passage to the salt molecules. This fact can be demonstrated by filling the funnel with a solution of white of egg instead of with pure water. It may be well to recall the infinitesimal size of molecules, estimated by Lord Kelvin to vary between a micro-micron and one-tenth of that inconceivably minute dimension. Of their shape, structure and chemical behaviour little is definitely known, but they are endowed with great energy, and the "colloid molecules," which are counted among the larger (*i.e.*, from 4—7 μ-μ. in diameter), have actually been identified microscopically under special conditions.

IV.—Metabolism a chemical process.

MATERIALS: *Seeds, mustard and cress; Indian corn; barley; nasturtium; bean, or corn plant; leafy shoots; blotting paper; small knife;* 10 *c.c. iodine solution; cardboard; neutral litmus paper; white vinegar; thick flannel.*

APPARATUS: *Test tubes; bell-jar; tumbler, or glass fruit-jar.*

(*A*) Grow some small seeds on blotting-paper. When well started, place them in a covered vessel so that the root-tips rest upon neutral litmus paper. Drop a little white vinegar upon similar litmus paper, and compare the result with that produced by the root tips after a few hours contact.

(*B*) Repeat PHENOMENA OF LIFE I. (*D*).

(*C*) Soak some barley seeds for a few hours in warm water. Divide into two portions (*a*) and (*b*). Split (*a*), and test for the presence of starch as directed in "PHENOMENA OF LIFE," I. (*C*).

Scatter (*b*) on thick flannel, moistened with warm water, and cover with a fold of flannel. Keep moist and warm (18° C. or 65° F.), until the barley is sprouting, *i.e.*, until the rootlet has grown the length of the seed. Test as above with iodine.

Record any changes indicated by these tests.

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* *Colloids* are a class of bodies including glue-like substances and also cellulose, which, when dissolved, do not pass through membranes. They often form jellies with water.

NOTE.—Enzymes or soluble ferments, are a peculiar class of substances, the secretions or products of living cells. By their presence they induce, under definite conditions, the chemical changes associated with metabolism.

The conversion of starch into sugar is effected by the agency of the enzyme diastase, which is secreted by the embryo as it develops during the process of germination. By this means the starch is converted into two forms of soluble sugar, which, by diffusion through the containing cell walls, are available for the nutrition of the plantlet.

A useful and interesting confirmatory test for the metabolic change which takes place in the barley may be afforded if the pupils are directed to chew very thoroughly some of the barley seeds used in (*a*) and (*b*). Disparity of results must, however, be anticipated in (*b*), as some palates are not able to detect the taste of sugar in the sprouting seeds.

V.—Respiration and Excretion.

MATERIALS: *Small shoot of green leaves; lime-water; taper.*

APPARATUS: 2 *lamp glasses; cork; saucers; glass tube, or straw.*

(*A*) Take two lamp glasses (*a*) and (*b*). Fit one end of (*a*) with a good cork (as *Fig.* 3), through the centre of which is passed the stem of a small shoot of green leaves, which will thus be suspended within the tube; fit (*b*) with a cork only. Test the capacity of the air within the lamp glasses to support combustion by holding a lighted taper for a few seconds within each of them.

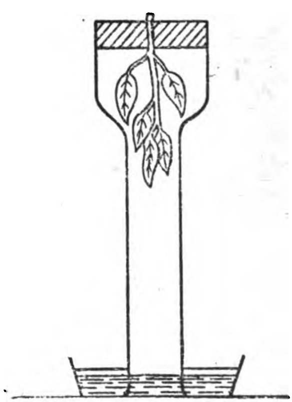

FIG. 3.

Stand the open ends of the lamp glasses in saucers of lime-water. Set aside for 24 hours, and then observe the condition of the lime-water in the saucers. Compare the result in (*a*) with that which follows deep expirations into a tumbler of lime-water, preferably delivered through a glass tube or straw. Once more test the capacity of the air within the glasses to support combustion.

(*B*) Thoroughly dry a bell-jar, and place a handful of fresh, leafy shoots beneath it. Observe the appearance of the glass after half an hour.

(*C*) Take a pot containing a thriving nasturtium, bean, or corn plant. Surround the stem with cardboard in such a way as to isolate the plant from the soil in which it is growing. Confine the leaves under a dry, inverted tumbler or glass fruit-jar. Observe the results at intervals for some hours.

NOTE.—The moisture thrown off (*i.e.*, excreted) by the leaves will collect upon the inner surface of the jars. The process is assisted in each case by placing the apparatus in strong sunlight during the observation. Careful examination of a portion of the epidermis of a leaf under a good hand-lens, or preferably under a microscope, will reveal the *stomata* and *pores* by which this process of excretion is carried on.

Reference to the "*Phenomena of Life*" II. (*C*), will recall the fact that air is essential to the development and maintenance of life. In this experiment attention is called to some of the *chemical* changes undergone by air in the process. During respiration the oxygen in air penetrates the plant-tissues, in order that, by the slow combustion, or *oxidation*, of the protoplasm of which they are composed, energy may be available for the internal work carried on in the plant. Consequently the air loses a portion of its oxygen, while, coincidently, waste products are formed as a result of the oxidation process. Of these the chief are *carbon dioxide*, *water*, and *salts*, which are *excreted* from the organism. That oxygen has been absorbed is shown by the fact that the air in (*a*) loses its power to support combustion. That carbon dioxide has been excreted is evident from the condition of the lime-water, in which a similar appearance can be brought about either by expiring into a vessel containing a small quantity, or by carrying out the experiments given in AIR IV. (*a*), (*b*), (*c*).

VI.—Observations upon Sensibility or Irritability. (Response to stimulus.)

MATERIALS: *Seeds, crane's-bill, oats; bean seedlings; sawdust; silver sand; garden soil; paper; pins; straw; water.*

APPARATUS: *Bell-jar; corks; fine-meshed sieve; sharp knife; shallow glass dish; Bunsen burner.*

(*A*) Rinse out a bell-jar with water. Suspend a specimen seed (crane's-bill) within it, and place the jar for some minutes over a shallow dish of water; then remove the crane's-bill. Lay it gently on a sheet of dry paper, and hold at a considerable distance above a Bunsen burner, or other source of moderate heat. Carefully observe the results.

NOTE.—The seed vessel will be observed to uncurl under the influence of the moisture, and to recurl when exposed to heat. These movements are caused by the swelling of the cell-walls. The cellulose walls of plant-cells are peculiarly prone to swell or shrink, according as their environment is moist or dry. Pupils must be reminded of the numerous sources of stimuli, such as gravity, light, temperature, moisture, chemicals, electricity, contact, or injury.*

Metchnikoff has also emphasised the fact that "irritability," which he defines as "cellular susceptibility," governs a great many of the vital phenomena in plants and in animals. It is this property, he says, which impels the branch towards the light and the root towards the ground; which directs the prolongations of the nerve cells towards the organs of sense, or towards the muscular fibres. Again, the sight of various kinds of food unconsciously stimulates to activity, by reflex action, different digestive glands. Indeed, the phenomena of living organisms which bear the sharpest impress of their physical and chemical nature may be classified as cellular "sensations."

(*B*) Take two pots of well-grown bean seedlings (*a*) and (*b*) and observe their appearance and condition. Put (*a*) in a warm place for a week, watering freely. Place (*b*) in a position to receive light from but *one* direction for a week. Note the results.

Reverse the conditions, and again compare after a week for the effects upon growth and development of the power to respond to stimulus.

(*C*) Take a well-grown bean seedling and fix the radicle to a cork with a pin. Arrange a straw so that it comes gently in contact with the sensitive portion of the root, close to the

* It was Sachs, the great physiological botanist, who pointed out that "we shall obtain from the process of irritability in plants, data for the explanation of the physiology of nerves." (*Julius von Sachs, German botanist, born 1832.*)

tip; place the whole on wet blotting-paper in a flat glass dish. Keep the plant moist by covering with a slip of glass, and observe that the tip will gradually curl away from the straw. (*Irritability.*)

(*D*) Take a fine-meshed sieve, sprinkle the wires with sawdust, and sow with oats. Soak well with water and suspend in a tilted position, so that the water accumulates on one side.

Observe the results on the growth of the oat rootlets, and record any evidence of *sensibility*.

(*E*) Fill a pot with alternate, well-defined layers of silver-sand and rich soil. Plant one or two germinating beans. Keep the pot for some weeks under good conditions of air, temperature, and moisture; then uproot the plant with great care, or lift out the contents of the pot without breaking them up.

Note the distribution of roots in respect of the contents of the pot.

(*F*) Take two sprouting beans, (*a*) and (*b*).

Cut off the extreme tip of the radicle of (*a*) with a sharp knife.

Attach each bean to a cork with a pin, and place both in a shallow glass dish containing a little water.

Watch from day to day for any difference in the manner of growth of the two radicles.

NOTE.—As the "perceptive zone" is removed in (*a*), the radicle will elongate horizontally, but will not grow downwards in normal fashion, having been temporarily deprived of its power to respond to stimulus.

Opportunity is again afforded for reference to the differentiation of parts in living organisms, to the functions performed by these parts in connection with nutrition, self-preservation or adaptation to environment, and to the index afforded to the well-being, or otherwise, of the organism by the character of these functional activities. Some suggestions would also be legitimate as to the susceptibility of the nervous system to injury or to the influence of its surroundings, with which may be associated illustrations selected from the pupils' own experience or within their range of observation.

VII.—Observations upon Movements.

MATERIALS: *Resurrection plant; seeds of crane's-bill; water; paper.*

APPARATUS: *Saucer; bell-jar; Bunsen burner.*

(*A*) Take a resurrection plant (*Selaginella lepidophylla*) and place it in a saucer of water; watch, and record the result of observations extended over several days.

(*B*) Procure some specimen seeds of the crane's-bill and subject them to treatment similar to that in VI. (*A*).

NOTE.—The *Selaginella* from the American deserts is now easily obtainable in England, and is excellent for demonstration purposes.

Illustrations and observations of plant-movement can be multiplied; as, for instance, the tendency of stalks or leaves towards bright light, or of the tendrils of creeping plants, such as sweet-peas, towards suitable forms of support, trellis-work, sticks, &c.

VIII.—Observations upon Energy and Heat Production during Metabolism.

MATERIALS: *Peas; cotton-wool; ¼ cake compressed yeast; 28 grams sugar.*

APPARATUS: *Large funnel; bottle; bell-jar; large scale centigrade thermometer; corks.*

(*A*) Fill a *large* funnel with germinating peas, and support it, as *Fig.* 4, in a small bottle, at the bottom of which is an inch of water. Cover the whole with a large bell-jar, through the mouth of which passes a large scale thermometer, of which the bulb is buried in the peas. Close the mouth of the jar with cotton wool. Note the temperature at the beginning of the observation.

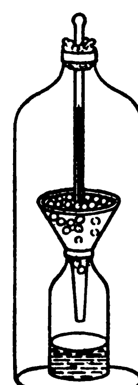

FIG. 4.

Keep the apparatus at about 20° C. (or 68° F.), and carefully watch any variations in the enclosed thermometer as the peas sprout.

(*B*) Make a mixture with yeast, sugar, and water as directed in "Phenomena of Life" I. (*a*), (*b*), (*c*), II. B. (2), and record the temperature when placed in the bottles, which are to be kept as there directed.

When good evidences of activity or energy are visible in (*a*), carefully introduce a large scale and sensitive thermometer into each, removing the cork as rapidly as possible, and supporting the thermometer with a large plug of cotton-wool. Record the temperature registered by the enclosed thermometer after two or three hours.

Repeat with (*b*) and (*c*). Compare the results.

NOTE.—Metabolic processes are specially active where growth is vigorous; the transformation of energy is borne witness to by a rise of temperature in the jar of peas of as much as 1·5° C. (or 2·7° F.), but the jar must be sheltered from currents of cold air.

IX.—Heredity and Individuality. Adaptability. Periodicity.

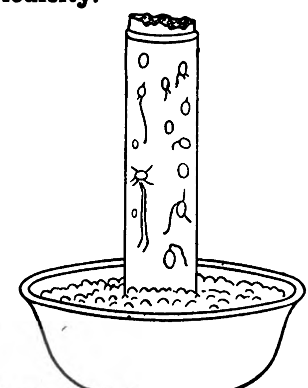

FIG. 5.

MATERIALS: *Sand; white paper; moss; selection of various kinds of small seeds.*

APPARATUS: *Lamp chimney; basin; wire; shallow dish.*

(*A*) Prepare a *germinator* as follows:—Stand a lamp chimney in a basin of sand. Make a roll of white paper to fit the chimney loosely, and place it inside the chimney; then fill the roll with lightly-packed moss, carefully moistened (*Fig.* 5).

Take seeds of various kinds (peas, beans, wheat, mustard, sunflower, Indian corn), and push them, with a loop of wire, into different positions *between* the roll of paper and the glass.

Set aside the germinator in the dark for two days, but keep the moss moist; then watch carefully for the changes which occur.

Note any differences to be observed during germination and growth in the individual seeds; such as the point from which the *radicle* appears; the form in which each *plumule* grows; the appearance of radicles and plumules in each kind of seed; whether they are exactly alike in each specimen of the same seed; also whether the direction of growth of stem and root is affected by the position in which the seed was placed in the germinator.

Carefully remove the contents of the germinator by first gently pulling out the roll of moss. Open out the paper case, causing as little injury as possible to the growing seeds; then place this bed of moss with the seedlings in a shallow dish, and keep under good conditions of temperature, moisture, and light for some weeks.

(*B*) Make careful observations and comparisons on the following points:—

(1) The general characteristics by which each seedling is to be recognised as belonging to a certain species or family.

(2) The special characteristics by which seedlings, even of the same species, can be distinguished from their companions.

(3) The devices by which the seedlings have adapted themselves to conditions more or less favourable to growth or development.

Note.—A study of the vegetation in any given area (in town or country, in hedgerow, herbaceous border, or near the sea), affords an introduction to the study of adaptation to environment in Nature. Where several species of trees or plants are struggling for existence, usually one or more becomes successful or dominant, on account of power to turn to account conditions of soil, shelter, air or light, favourable to growth and nutrition.

Some display this faculty of adaptability to circumstances in the shape or position of their leaves, which may be thick and fleshy in dry climates, in order to give off but little moisture, or long and thin where the rainfall is heavy, in

order to drain rapidly. In temperate climates, the whole surface of broad leaves is exposed to the sunshine, whereas in hot countries only the edges of the leaves are turned to the light.

The very organs for climbing, developed by plants in order the better to adapt themselves to their surroundings, are differentiated according to their needs; the honeysuckle makes use of its stem for the purpose, vetches have modified their leaflets into tendrils, while blackberries climb into the light and air by the aid of "prickles."

Turning to the animal world, illustrations of this characteristic are found in the protective colouring of birds and animals and insects, in the habit of hibernation and in matters of food. Numerous examples of such adaptation to environment can be selected from popular books on natural history, but in man it has reached its fullest development; he alone can adapt himself to all climates and to every variety of diet; though where this quality is prematurely overtaxed, general efficiency is often seriously impaired.

It is useful to trace out the rhythmic processes to be observed both in the inorganic and organic worlds. Such rhythms are astronomical, meteorological, geological, biological, physiological, historical, etc., in character, and they may be epochal, seasonal, lunar, weekly, or diurnal, in their recurrence. In the animal world, these rhythms may be described as habits of organic activity which have proved advantageous, for which reason they have probably become highly developed in man. To the student of hygiene their influence is of much interest, throwing light as it does on nature's laws, which are designed to promote conditions of healthful growth and efficiency in plants and animals.

The following series of illustrations can be classified under the heads of inorganic or organic rhythms by the pupils, and others, of which many exist, can be collected:—The seasons; day and night; blossoming of flowers; flights of migratory birds; hunger; tides; revival of insect activity; infancy; childhood; maturity; old age; rise and fall of civilisations and dynasties; hibernation of many vertebrates; planetary revolutions; movements of the heart; peristaltic action of the œsophagus and intestines; seasonal protective colouration in birds and animals; sleeping and waking; variations in muscular strength or in the temperature of the body; leafing and fruiting of trees; prevalence of disease; increase in height and weight; vigour and fatigue; activity and rest, etc.

X.—Observations upon Growth.

MATERIALS: *Bean seedlings; red ink; pen; cotton-wool.*

APPARATUS: *Thistle funnel; glass-jar.*

(*A*) Take a well-developed bean seedling and place it carefully in a thistle funnel, so that the radicle passes down the tube; mark on the outside (with red ink) the point to which it reaches in the tube. Cover the bean with moist cotton-wool and support the whole in a glass jar, at the bottom of which is placed a little water. This must be replenished when necessary, as moisture is necessary to ensure healthy and normal growth. Examine daily, and mark with red ink the point reached by the radicle.

NOTE.—Attention can also be directed to any growing plants, or to home or school pets when young, or to observations on the measurement of pupils made at recurring intervals, to illustrate the association of growth with active life, especially in youth.

(*B*) Take six broad bean or other seedlings, each in its own pot, (*a*), (*b*), (*c*), (*d*), (*e*), (*f*), as nearly similar in size as possible, and keep each as directed:—

(*a*) Under the best conditions for growth:—adequate sunlight, warmth, moisture, protection from worms and slugs, etc.

(*b*) Under similar conditions to (*a*), minus light.

(*c*) Under similar conditions to (*a*), but with light from one side only.

(*d*) Under similar conditions to (*a*), except that it is placed in the lowest temperature available above freezing.

(*e*) Under similar conditions to (*a*), minus moisture.

(*f*) Under similar conditions to (*a*), but allow access to some insect pest.

Maintain these conditions for one week, then compare the results.

NOTE.—The strong, inherent power of growth will prove powerful enough to overcome very adverse conditions for periods of

greater or less length, according to the species and the individual vitality of the specimens selected for experiment; but the evidences of effort and stress, and the results on vigour, symmetry, even on life, will serve to stimulate the interest of older pupils to observe and compare corresponding results on animal and human life.

XI.—Reproduction.

Reference to this essential activity should not be entirely omitted at this point; the phenomena should be presented, as Prof. J. A. Thomson advocates, in their biological setting. "Natural curiosity should be frankly, truthfully, and *gradually* satisfied as it arises." Children early become more or less familiar with the broad facts of heredity, *i.e.*, that like begets like, both in the vegetable and animal worlds; and are well aware of the immature condition in which many young organisms start their separate existences. They realize almost unconscioully that the power to transmit life is a great, world-wide process; and, with equal unconsciousness, observe for themselves some of the changes which occur during the early stages of growth; as, for example, in tadpoles, chicks, or kittens.

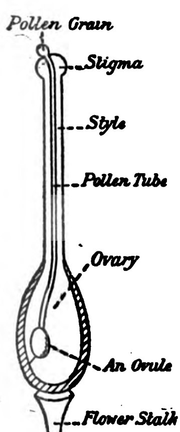

FIG. 6.

NOTE.—Nature-Study now furnishes an introduction to some of the devices which exist for the purpose of perpetuating the varied forms of life in the earth, asexual and sexual. In the course of such lessons, the act of fertilisation as a part of the process in plants will probably be explained, to secure the accomplishment of which the pollen grain sends out a tube, the *pollen tube*, as in the Madonna Lily (*Lilium candidum*), which grows down the *style*, and enters the *micropyle* of the *ovule*, within which the *ovum* lies hidden (*Fig.* 6).

Though the intricacies of the process do not permit of explanations suited to the simplicity of a child's mind, a general conception can be formed, and the fact presented that in animals, and also in plants, fertilisation, or the inti-

mate and orderly union of two microscopic living cells, the sex nuclei, is associated with all the higher forms of reproduction; for which purpose the comparison of fertilized eggs with seeds is convenient and legitimate. Illustrations should also be given of the provisions usually present for the protection or preservation of the latent life within the seed or egg, in the form, for instance, of an outer covering or as a store of nutriment; and of the dependence of life, in every case, on warmth and other conditions for germination and growth.

XII.—Illustration of Nature's care for early stages of Life.

MATERIALS: *Seeds; shoot from chestnut tree; blotting paper; litmus paper; water.*

APPARATUS: *Covered vessel; sharp knife.*

(*A*) Repeat "Phenomena of Life," I. (*D*), noting the consumption of the *endosperm* by the developing seed.

(*B*) Examine a budding shoot from a chestnut tree. Notice the provision made to guard the shoot from injury.

(*C*) With a sharp knife, cut open a chestnut bud lengthwise, and observe:—

(*a*) The closely-laid scales and their character.

(*b*) The sticky secretion which holds the scales together and prevents the entrance of water.

(*D*) Examine the position of the leaves in a fresh, growing shoot. Distinguish by this arrangement the provision made for their nutrition by sun and rain.

NOTE.—A comparison of seeds, nuts, buds, etc., can be made with the object of detecting and impressing on the pupils' minds the many devices employed in nature to secure the early stages of life from injury.

IV.—CONDITIONS BY WHICH LIFE IS AFFECTED.

I.—The Influence of Nutrition.

MATERIALS: *Seedlings, as corn, bean; labels; iron sulphate; vaseline; sweet oil; nutrient solution (with and without iron salt); water.*

APPARATUS: *Test tube; cork; 3 beakers; bell-jar.*

(*A*) Take two pots of seedlings and label them (*a*) and (*b*). Supply (*a*) with nutrient solution daily for a week. To (*b*) give water only.

Compare the results after a few days.

(*B*) Take two grains of corn, (*a*) and (*b*), which have sprouted in water. Suspend the radicle of (*a*) in a test tube (or small glass cylinder) filled with nutrient solution, and support the seed by passing the plumule through a nick in the cork. Arrange (*b*) in a similar way, but supply nutrient solution from which the iron salt has been omitted. Place both seedlings in a good light and observe the results.

NOTE.—(*a*) will develop a large stalk, flower, and produce seed, with with which the experiment can be repeated. (*b*) will remain colourless, and its normal condition can be restored only by the addition of a trace of iron sulphate to the solution in which its radicle is immersed. Under all circumstances, plant life depends upon carbon for building its organic substance. This it obtains from the carbon dioxide in the air, which is received and elaborated by means of its *chlorophyll* containing cells. The green chlorophyll bodies do not develop in the absence of iron salts.

(*C*) Air a factor in good nutrition. Take three well-grown bean seedlings (*a*), (*b*), (*c*), and place each in a glass-jar or beaker two-thirds full of water.

Keep (*a*) under the most favourable conditions of environment. Cover (*b*) with a bell-jar, sealing the edge with vaseline. Cover the surface of the water in (*c*) with a film of sweet oil.

Observe the behaviour of the seedlings day by day.

II.—The Influence of Environment.

Materials: *Seeds (mustard and cress); sand; flannel; water.*

Apparatus: 4 *small pots; bell-jar; balance; flat dish.*

(*A*) Sow the seeds in small pots of moist sand, (*a*), (*b*), (*c*), (*d*). As soon as signs of growth are apparent, treat them as follows, place:—

(*a*) In the dark.
(*b*) In the light.
(*c*) Under the bell-jar.
(*d*) Where the light falls on one side only.

Examine after a week, and note the differences to be observed as regards:—

(1) Size.
(2) Symmetry.
(3) Appearance.
(4) Strength of stem.
(5) Colour.

Weigh a specimen of each seedling, and compare the exact weight in each case; note to what extent the nutrition, as evidenced by weight, has been affected by the surroundings.

(*B*) Take two pieces of moist flannel, (*a*) and (*b*). Sow mustard and cress seeds very thickly on (*a*); scatter them only sparsely on (*b*). Lay both (*a*) and (*b*) on a flat dish, keep moist and under conditions favourable to growth.

When the seedlings have grown for a fortnight or three weeks, examine individual specimens from both (*a*) and (*b*). Record any results apparent from the overcrowding of the seeds in (*a*).

V.—SOME CHARACTERISTICS OF AIR.

General Presence of Air. Some Properties of Air. Constituents of Air.

DIRECTIONS.

(1) To cut Glass Tubing.—File a scratch on the glass with a triangular file; then bend the tubing slightly, pulling it outwards at the same time.

(2) To round Cut Ends.—Hold just inside the Bunsen flame, and slowly revolve.

(3) To bend Glass Tubing.—Take care that the tubing is perfectly clean and dry inside and outside before heating. Hold the tubing in the hottest part of an ordinary gas flame, and revolve it slowly but constantly until the heated part is quite soft. Withdraw from the flame, and gently bend it to the required form.

(4) To draw out Glass Tubing to a Pointed End.—Heat a piece of tubing near the top of a Bunsen flame, taking care to keep it revolving. As the glass becomes hotter and softer the walls will fall in. Remove from the flame, and gently but steadily draw the ends a little apart. When cool, separate with the file at the narrowest part.

(5) To bore Corks.—Always choose a sound cork a little too large for the vessel it is required to fit. Roll it on the floor under the foot until it is soft; it will then be the right size. Bore a hole with a cork-borer, which should first be moistened, beginning to bore at the narrow end of the cork. The diameter of the cork borer should be slightly smaller than the hole required.

(6) To prepare a Filter.—Take a piece of filter-paper; fold it once across, then fold again in two. Open the paper so that it forms a cone of three thicknesses on one side, and one on the other. Fit this into a glass funnel, so that it rests firmly in contact with the sides, and moisten with water, in order that the filtration may be more rapid. The paper should never project above the edge of the funnel. Pour the liquid to be filtered down a rod upon the side of the paper, otherwise it may be lost by running down the outside of the containing vessel.

(7) To prepare Nutrient Gelatine.—*Water*, 1 *litre; Liebig's extract*, 5 *grams;* 100 *grams gold-leaf gelatine; peptone*, 10 *grams; salt*, 5 *grams; sodium carbonate, to neutralize; the white of an egg, to clear; steam sterilizer; double boiler or saucepan; stirring rod; funnel; filter paper; litmus paper; flask (or tubes) to receive the nutrient gelatine; cotton-wool to plug above, after sterilization, when the moist cotton-wool previously employed must be discarded.*

METHOD.—To make the nutrient gelatine, mix the Liebig thoroughly with the gelatine, peptone, and water. Place in the double boiler, and heat for about half-an-hour. Neutralize by adding sodium carbonate, till red litmus paper just turns blue. (This is an important point, as if the nutrient material be perceptibly acid or alkaline, it will not support the growth of both moulds and bacteria.)

Boil for about an hour, add the white of one egg to clarify the liquid and settle the albuminous matter, and boil a few minutes longer. Filter while hot through filter paper into sterilized flasks or test tubes, and plug each with cotton-wool. Care should be taken to keep the unfiltered gelatine hot, and to wet the filter-paper with hot water before beginning to filter. Sterilize the gelatine in a steam sterilizer, or large fish-kettle, twenty-five minutes a day for three days in succession. If the gelatine is found to be acid at the beginning of filtration, it must be neutralized again. If thoroughly sterile, this nutrient gelatine should keep a long time under proper conditions.

(8) TO PREPARE AND COLLECT OXYGEN GAS.—Fit a rubber stopper with one hole, through which passes a piece of bent glass tubing, into a *hard* glass flask or test tube. Fit up as *Fig.* 7. (This arrangement of

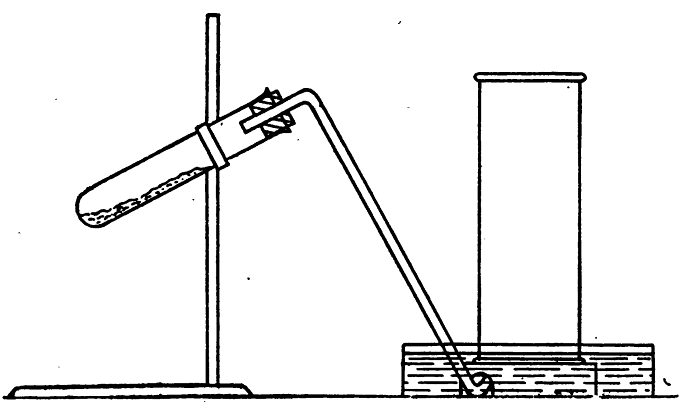

FIG. 7.

apparatus is that most usually employed for the collection of gas. Mix about equal quantities of potassium chlorate and manganese dioxide, and place the mixture in the tube. Fill several jars or bottles brimful of water; cover with glass plates, and invert them in a trough, carefully removing the plates under water.

Gently warm the flask or tube, slowly and evenly, by playing the Bunsen flame on different parts, and place one of the jars over the end

of the delivery tube. As the oxygen gas is given off, it displaces the water and gradually fills the jar.

When one jar is full, cover its mouth *under water* with a glass plate greased with vaseline; lift it out of the trough, and set aside till required. Proceed to fill the requisite number of jars in the same way, but be careful to remove the flask and delivery tube from the water *before* removing the source of heat.

(9) To construct a simple Air-oven for Sterilizing Purposes.—Take a large, square biscuit-tin with a well-fitting lid. Make a circular hole in the centre of the lid large enough to receive a flat (preferably rubber) cork, about 3½ cms. (1½-in.) in diameter.

Insert in the cork (*a*) a thermometer which will register up to 250° C. or 300° C. (500° or 600° F), (*b*) a piece of glass tubing through which steam may escape. The cork and these fittings should be air-tight. Have a tray or shelf of galvanized-iron wire fitted within the tin, to raise the substances enclosed in the air-oven at least two inches from the bottom, where the temperature will be higher than elsewhere.

Raise the tin, when thus fitted, above the source of heat (gas or oil) on an iron stand or on two bricks.

(10) To sterilize Glass Vessels for the Culture of Micro-Organisms.—Thoroughly wash the Petrie dishes, flasks, or test tubes in soap and water, and rinse so that the glass is quite clear. Wash out with 25% hydrochloric acid. Wash again, but with distilled water, to ensure the absence of any mineral deposit. Drain, and replace the lids, or plug with cotton wool. Place the clean vessels in the hot air oven, which should be cool to start with, and raise the temperature until high enough to bake bread or to colour a piece of bread crumb (about 80° C. or 176° F.), and keep at this temperature for an hour.

Remove the source of heat, and allow the oven to cool. Then remove the contents, and keep the dishes sealed by passing a rubber band round each to prevent any risk of falling open. They can be set aside till required, and will remain sterile until the covers are removed.

(11) Rapid Sterilization.—If tubes or flasks are required in a hurry, they may be rapidly sterilized as follows. Wash in water, rinse with alcohol, and then with ether. Dry by warming carefully over a Bunsen flame. The ether vapourises and burns at the mouth. When dry, plug with sterilized cotton-wool and flame the tube well till too hot to hold. Then allow to cool.

To sterilize cotton-wool, take a 3-inch strip, twist tightly, fold in half, and pass two or three times through the flame of a Bunsen burner or spirit lamp, until slightly scorched; immediately insert as a plug.

I.—Illustrations of the General Presence of Air.

MATERIALS: *Water; lump of sugar; dry earth; taper.*

APPARATUS: *Test tubes; 4 tumblers; bottle; 2 flasks; rubber cork with two holes; funnel; glass tubing; beehive cell; pan; tripod; retort-stand.*

(*A*) Plunge a small, dry, *empty* test tube straight down into a tumbler nearly full of water. Observe the results, and compare with what follows when the test tube is slightly tilted, with the mouth still kept below the water level.

NOTE.—The fact that the water fails to enter the test tube when it is plunged vertically into the vessel testifies that no vacuum exists; the nature of the contents is shown when, on tilting the test tube, bubbles of air escape.

This demonstration is more effective when a large glass vessel can be used, and the tilted test tube held below the surface of the water, to increase the pressure.

(*B*) Take a bottle and fit it firmly with a rubber cork, pierced with two holes through which have been passed a funnel and a piece of glass tubing, the latter bent at right angles. Place a finger over the open end of the bent tube and pour water into the funnel. Then remove the finger and hold it at a distance of half an inch from the tube. The sensation of escaping air is distinctly felt as the water enters the bottle.

NOTE.—If this experiment be used for class demonstration the fact that it is the contained air which prevents the entrance of water into the bottle until an outlet is provided can be more forcibly illustrated if a lighted taper be held at the outlet when the finger is removed, the flame will be violently agitated by the rush of escaping air.

(*C*) Take two tumblers filled with water (*a*) and (*b*). Into (*a*) drop a lump of sugar; into (*b*) drop a lump of dry earth.

Compare the results in each case with those which accompany the tilting of the test tube in I. (*A*).

NOTE.—This demonstration can be repeated, and the fact of the general presence of air in solids emphasized, by employing other suitable substances.

(*D*) Gently warm a flask of freshly-drawn water.

(1) Note results as the temperature rises. The bubbles consist of air which is dissolved in the water, and which is driven out owing to the expansion by heat of the constituent gases of which it is a mixture.

(2) To prove that the bubbles in the heated water are air, collect them in a test tube as follows:—Fill a flask brimful of water. Pass a glass tube (*Fig.* 8) through a rubber cork, and fit firmly but gently into the flask. Fill a test tube full of water, and invert it, under water, over the beehive cell, previously placed in a pan of water supported upon an iron tripod. See that the tube is full of water also.

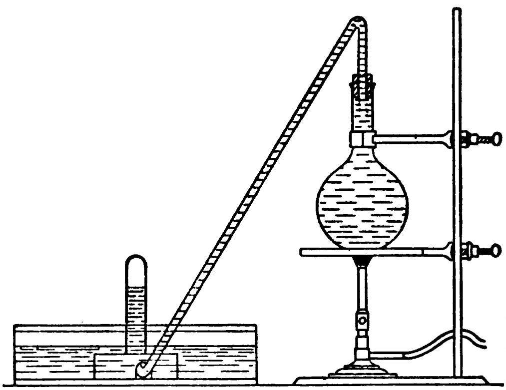

FIG. 8.

Fit up as figured. Apply gentle heat from a Bunsen burner or spirit lamp.

When the air expelled from the flask has filled the tube by displacing the water, disconnect the flask before removing the source of heat; light a taper; cautiously raise the tube until its mouth is just above the level of the water, and test the contained gases by introducing the lighted taper. If they support combustion for a few seconds, it is fair to assume that the bubbles are present in the form of air.

NOTE.—This demonstration can be connected with the study of the behaviour of gases held in solution. Some, such as nitrogen, hydrogen, and carbon monoxide are very slightly soluble in water; others, such as ammonia and sulphur dioxide, are very freely so. The hygienic importance of the *character* of the gases contained in solids and liquids should be emphasized.

II.—Some Properties of Air.

MATERIALS: *Water; cardboard; rubber tissue; fine rubber band; filter paper; paper or shaving spiral; tissue paper; pastille paper; taper; candle; matches*; 2 *pencils or blocks of wood; bottle of commercial methylated spirit or peppermint essence; tinted water.*

APPARATUS: 4 *large flasks; rubber corks,* 1 *with a valve; tumbler; test tubes; shallow dish; small bottle; glass tubing; narrow gas jar; lamp chimney; air pump; Bunsen burner; balance*; *retort stand; a workman's breakfast can; bicycle pump; rubber tubing; pinch-cock.*

(*A*) *Air Possesses Weight.*

(1) Take a very large flask or, preferably, a workman's breakfast can, from which the air has been previously exhausted by means of a good air pump, and of which the mouth is closed with a rubber cork in which a valve has been fitted, such as is fixed in the rim of a bicycle wheel.

Counterpoise the flask (or can) carefully in a delicate balance, and record the weight. Attach a bicycle pump to the valve and pump the flask or can full of air. Watch the evidence afforded by the balance of the weight of the entering air. Counterpoise again, and note the increase in weight which has taken place.

(2) Take a round-bottomed flask with a capacity of 500 c.c. (1 pint). Fit with a rubber cork, through which passes a short length of glass tubing to which is attached a piece of rubber tubing with a pinch-cock. Put a little water in the flask and boil, using a small flame. When steam issues freely from the flask, close the pinch-cock; cool the flask, suspend by a wire loop to one arm of a delicate balance, and counterpoise with great accuracy. Light a taper, hold it to the mouth of the rubber tubing and open the pinch-cock. The inrush of air will be demonstrated both visually and audibly; its weight will also destroy the accurate balance of the flask; note what additions are necessary to restore the counterpoise.

NOTE.—It is possible to suck enough air with the lips out of a *flask* to show a difference of weight with a not very delicate balance.

(*B*) *Air Exercises Pressure.* Fill a tumbler brimful of water and cover with a piece of card; invert rapidly, being careful to hold the vessel upright when inverted.

Note.—A large vessel of water can be used if care be exercised, as the atmospheric pressure of about 15 lbs. to the square inch can support considerable weight if the inverted vessel be held absolutely vertical. Many other illustrations of this fact are available, as, for instance, a boy's sucker, a pipette, a pair of bellows, &c.

Reference can advisedly be made to some of the causes which influence variation of atmospheric pressure; and the construction, principles, and employment of the barometer, by which the variations can be accurately gauged, may be explained.

(*C*) *Expansion and Contraction of Air.*

(1) Close the mouth of a large test tube perfectly air-tight with rubber-tissue. Heat the other end of the tube gradually until the rubber is forced outwards. Allow the tube to cool until it is just bearable to the hand; then plunge it in cold water, and observe the evidence of air contraction.

Note.—Do not carry the heating far or the tube will burst.

(2) Remove the rubber, and invert the test tube in a shallow dish of water; mark, with a fine rubber band, the level to which the water rises in the tube. Heat the test tube very thoroughly, again invert in the water, cool quickly by covering the tube with a small pad of cold, moist filter paper, and mark the level to which the water now rises.

Note.—The employment of thermometers for indicating and recording variations in atmospheric temperature can here be explained; the following reasons being given for the general use of mercury for the purpose. As a thermometer may be required to indicate variations of temperature extending over a very wide range, it is essential to fill the glass tube of the instrument with a substance sensitive to slight variations in temperature, but which has a high boiling point and which does not easily solidify with cold. Water is clearly inadmissible for the purpose, though alcohol is useful on account of the wide range of temperature between its boiling and freezing points.

Mercury, however, has a very high boiling point (357° C., or 710° F.), and solidifies only at $-40°$ C. ($-40°$ F.), a temperature much lower than that usually attained by the air; it therefore meets every requirement of a thermometer to be employed for ordinary purposes. Reference can also be made to the Law of Charles, dealing with the expansion of gases.*

(3) *A further illustration of the properties of Air* (*cf.* (*B*) *and* (*C*)). Heat a test tube gradually but very thoroughly, and press it immediately and firmly on the back of the hand, to which it should cling with some firmness, the skin of the hand being drawn up inside the tube.

NOTE.—It is well to be sure that the point is perceived that when the air in the tube contracts by cooling, air pressure in the tube is reduced. The skin is therefore "pushed up" into the tube during the cooling process owing to the greater pressure of the external air, and is also "sucked up" on account of the partial vacuum caused by the heating and consequent expansion of the air present in the tube.

(*D*) *Rarefaction of Air.*

(1) Attach a spiral of paper or shaving to the upper ring of a retort stand, and place it above a Bunsen burner or a spirit lamp. Protect from draughts, and note the movements which take place as the hot air rises.

(2) Scatter some very small scraps of tissue paper just above a gas burner or a red hot poker, and note the direction given to the particles by the current of heated air.

NOTE.—These demonstrations serve to introduce the elementary principles of air currents, and their bearing upon ventilation, and upon draughts and their causes. They also afford illustration of two modes by which heat is transmitted, *viz.*, radiation and convection.

It is evident from *C* (1) that air expands when heated. The fact is demonstrated in *D* (1) and (2) that, given similar conditions of pressure, heated air becomes lighter, *i.e.*, rarefied. Consequently it rises in a column through the

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* In its simplest form the Law of Charles may be expressed as follows:—"The volume of any gas varies directly as the absolute temperature." The fact that all permanent gases have their own co-efficient of expansion, similar in character to the co-efficient of expansion of solids and liquids, was discovered by John Dalton (1766—1844), the author of the atomic theory. But whereas the co-efficient of expansion is a variable, but always a very slight fraction, in solids and liquids, it is not only a very considerable fraction, but always the same, in all permanent gases, namely, $\frac{1}{273}$ of their volume at 0° C. (32° F.), which scarcely varies within even wide ranges of temperature.

colder air by which it is surrounded, some of which colder, heavier air rushes in to take the place of that which has risen. A circulation of air currents is, therefore, the result of this variation in density. The paper spiral remains motionless while the atmosphere in which it is suspended is of the same density; but when the air below it is rarefied by the heat applied, the currents of air so created cause the spiral to revolve.

Similarly, the scraps of paper are carried up in the stream of light, hot air above the gas burner or poker; they ascend just so high as it rises, but fall when the air becomes less rarefied from admixture with the surrounding colder, heavier air.

This popular explanation should be supplemented by the scientific one, in order that the vast importance of the force of gravity in natural ventilation may be properly appreciated. Air under the same pressure and at the same temperature always has the same specific gravity. If the pressure on any volume be lessened, or the temperature be raised, that air expands in definite proportion. The volume increases and the specific gravity is correspondingly lower. The adjacent air, which is denser, forces the lighter air out of place, and causes it to rise, and thus a current of air is set up. On the other hand, if a volume of air be cooled, it contracts, and its specific gravity becomes higher. Owing to its greater density, this cooler air falls and displaces the warmer, lighter, adjacent air and causes it to rise. Thus, whenever variations of temperature occur in the atmosphere, movement must result, and air-currents are established.

(*E*) *Circulation of Air.*

(1) Ignite a bunch of pastille paper, and allow it to smoulder. Notice the direction of the smoke, and the gradual diffusion of both smoke and scent.

(2) Remove the stopper from a bottle of commercial methylated spirit, peppermint essence, or other strongly odorous substance, and make observations on the time which elapses before the result is generally perceived by those present in the room.

NOTE.—The odour will permeate the room with greater or less rapidity, according to the force and direction of the air currents.

(*F*) *Compressibility and Elasticity of Air.*

(1) Fill a small bottle half full of water; insert an air-tight rubber cork through which passes a glass tube drawn to a fine point at the outer end and having the other end reaching nearly to the bottom of the water. Blow strongly through the tube; quickly remove the end from the mouth. The water will be forced out, its impetus varying with the amount of additional air that has been forced into the bottle.*

(2) Plunge a dry test tube, mouth downwards, into a narrow gas-jar containing tinted water. Observe the level of the water in the tube according to the pressure exerted by the head of water. Raise the tube, and again note the water-level in it.

NOTE.—A "head" of water means the height of water above the point under consideration in any calculation; in this case, the height of the water in the gas-jar above that in the test tube. It will vary according to the depth to which the tube is submerged by the pressure of the student's hand.

(*G*) *Air Supports Combustion.*

(1) Set a piece of two-inch candle on the table and light it. Notice the appearance of the flame.

(2) Put a clean dry tumbler over the candle and watch results. Lift the tumbler, and promptly introduce a lighted match when the smoke which accompanies the extinction of the candle flame has cleared away.

NOTE.—The glass becomes misty and the flame gets rapidly smaller and becomes blue; it is soon extinguished, a column of smoke rising, *i.e.*, the contained air no longer supports combustion.

The dew forming upon the inner surface of the tumbler (which is cool) is condensed watery vapour, always a product of combustion. Combustibles such as wax, oil, tallow, or paraffin, contain *carbon* and *hydrogen*, which are liberated by the act of burning. The carbon burns in the oxygen of the air, and whilst burning much of it unites with oxygen and forms carbon dioxide, a gas; the hydrogen also burns, and in burning unites with the oxygen and forms water.

* Boyle's Law states that the "*The volume of a gas is inversely proportional to the pressure.*" *The greater the pressure the less the volume.*

Robert Boyle, a celebrated British chemist and natural philosopher, lived 1627—1691.

(3) Set a lamp chimney supported on two pencils or blocks of wood, over a similar piece of lighted candle, and observe the flame. Then hold a slip of tissue paper near the base of the chimney; how is it affected? Compare the results with those which follow the removal of the blocks or pencils.

(4) Re-light the candle, re-place the chimney upon the supports, and cover the top with a piece of thick cardboard. Remove the cardboard, and introduce a lighted taper quickly into the chimney, and compare the results with (2).

Note.—In (3), success can only be obtained if great care be taken to protect the apparatus from draughts.

Attention should be directed to simple methods of extinguishing fire by the exclusion of air, and observation should be exercised on the reasons for dampers in kitchen stoves, holes in Bunsen burners, etc.; the various devices employed to supply air to lamps and gas burners may also be discussed.

It should be emphasized that where artificial light is employed additional ventilation is immediately necessary; whereas it is a common domestic practice to close windows and shutters all over a house at the hour when the necessity for artificial light increases the demand for adequate air supply to the inhabitants.

III.—Some Constituents of Air.

Materials: *Filter paper; stamp paper; 2 jars of oxygen; 1 jar of carbon dioxide gas; lime-water; wood charcoal; magnesium ribbon; phosphorus; hydrochloric acid; ice; taper.*

Apparatus: *Bell-jar; metal capsule; stoppered glass-jar; glass rod; flat glass dish; deflagrating spoon; bright tin cup; flask; glass tube; thermometer; Bunsen burner.*

(A) Air a Mixture of Gases.

(1) Lower a lighted taper into a bell-jar and carefully observe what follows.

(2) Take a piece of phosphorus half the size of a pea, dry it carefully on filter paper and place it on a metal capsule. Float this on water and cover with a stoppered bell-jar.

Fill up water outside to the level it has reached within. Mark this level with a strip of stamp paper, and divide the remainder of the jar into five equal parts by means of a scale marked on similar paper. Ignite the phosphorus with a hot glass rod and insert the stopper. When the fumes have cleared, add water to equalize the level inside and outside the jar. Remove the stopper, and instantly lower a lighted taper into the jar. Compare the result with (1). Replace the stopper.

(3) Take a jar of previously prepared oxygen, carefully covered with a greased plate. Invert it over the bell-jar, being careful to hold the greased plate firmly in its place while doing so. Remove the stopper from the bell-jar, and rapidly slip the plate away as the jar of oxygen is lowered over the mouth of the bell-jar. Fix the jars in this position for ten minutes (*Fig.* 9). Then remove the gas-jar, and again test the contents of the bell-jar with a lighted taper.

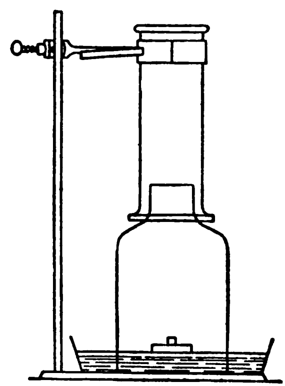

FIG. 9.

NOTE.—Impress the fact that phosphorus must always be handled under water, and by the aid of forceps, *never with the fingers.* The fact that the chemistry of air will, in almost all cases, be dealt with in detail in the course of elementary science work precludes the necessity of treating it fully in this place. This experiment is, however, of special interest, as it affords clear proof that the normal character and properties of air can be restored after combustion, by the introduction and diffusion of oxygen.

(4) Place a little lime-water in a flat glass dish. Leave exposed to the air, and note the results.

NOTE.—It is advisable to afford foundation for the conclusion to be deduced from this observation, and the following experiments will prove the action of carbon dioxide on lime-water.

First make the gas by placing a small piece of wood-charcoal, *i.e.*, pure carbon, in a deflagrating spoon; igniting and lowering it into a gas cylinder full of oxygen. When it ceases to burn, add a little lime-water to the product. Shake the jar. It is evident that the milky effect produced by the combination of lime-water with the gas which results from the combustion of pure carbon in oxygen is similar to that which is visible when lime-water is exposed to air, and suggests that the same gas is present in both cases.

To prove that carbon is actually present in carbon dioxide gas, burn a strip of magnesium ribbon in an empty gas-jar and call attention to the character and white appearance of the ash. Then attach another strip to a deflagrating spoon, and lower it into a jar of carbon dioxide gas. When combustion has ceased, apply hydrochloric acid to the ash in both jars. Shake well, and compare the results.

Magnesium ribbon burned in an atmosphere of carbon dioxide decomposes the gas, forms magnesium oxide, and throws down the carbon in powder. By the addition of dilute hydrochloric acid the calx of magnesium is dissolved and the black specks of carbon are more readily visible.

A saturated solution of barium hydroxide gives excellent results, should lime-water prove unsatisfactory.

(*B*) *Air contains Aqueous Vapour.*

(1) Place some cold water in a bright, tin cup, and slowly add small pieces of ice, stir with a thermometer and notice the point at which deposit of "dew," *i.e.*, moisture, takes place on the outside of the cup. Slowly add water, continue to stir, and observe the temperature recorded by the thermometer at the moment the dew disappears.

(2) Boil some water in a flask, the only opening from which is a narrow glass tube bent at a right angle to the flask. Keep the water boiling, and hold a lighted spirit lamp or Bunsen burner under the jet of vapour; observe the results when the flame is brought nearer to, or removed further away from, the issuing jet.

NOTE.—The constant presence, but very variable proportion, of aqueous vapour in the air under all conditions, and the connection of this proportion with temperature and meteorological conditions should be explained.

Allusion should be made to the lassitude experienced on close, damp days, when the excess of moisture in the atmosphere interferes with insensible perspiration, and the brisk sensations associated with crisp, dry weather, when normal evaporation takes place from the surface of the body.

Reference can also be made to frost on the window-pane, "seeing the breath," &c.

IV.—Sources and Character of Air Pollutions.

MATERIALS: *Fine wire; thick cardboard; decaying vegetable matter; nutrient gelatine; rubber band; weak solution of permanganate of potash; rubber finger-stall; oil; lime-water; water; candle.*

APPARATUS: *Tumbler or glass jar; lamp chimney; glass tubes; wide-mouthed bottle; large round-bottomed flask with rubber stopper; rubber tubing; pinch-cock; cork; thistle funnel; Petrie dish;* 2 *glass slides; hand lens; mirror.*

(*A*) *Combustion and Sources of Carbon Dioxide Gas.*

(1) (*a*) *Combustion.* Invert a tumbler or glass-jar over a burning candle until it is extinguished; pour a little clear lime-water into the vessel and compare the results with "Some Constituents of Air," (*A*) (4), *p.* 51.

(*b*) Set a lamp chimney over a lighted candle. Fix a short length of fine wire, bent into a very small loop at one end, into a piece of thick cardboard. Dip the wire loop into clear lime-water, which must form a film across the loop. Cover the lamp chimney with the cardboard, letting the wire hang inside.

Examine the film about two minutes after the flame goes out, and observe any evidence it affords of atmospheric impurity.

(2) *Respiration.* Pour a little clear lime-water into a tumbler; shake it well, and note any result.

Breathe repeatedly through a glass tube into the tumbler; shake again, and observe carefully.

(3) *Putrefaction.* Take a wide-mouthed bottle partially filled with decaying vegetable matter; fit with a good cork, through which passes a thistle funnel and a glass tube bent twice at right angles; the long limb of the tube should be connected with a small tumbler half-full of lime-water. Pour water down the thistle funnel. The gaseous contents of the bottle displaced by this process will be forced into the lime-water, which will afford obvious evidence of their character (*Fig.* 10).

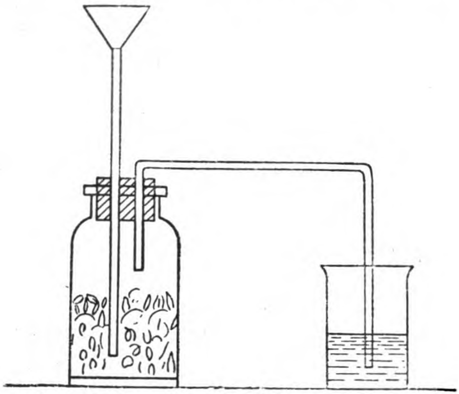

FIG. 10.

NOTE.—The dead leaves or vegetable refuse should be collected in the bottle a few days before they are required, moistened, and kept closely corked.

The thistle funnel must reach almost to the bottom of the bottle; the escape tube should merely pass through the cork.

(*B*) *Organic Impurities.*

(1) Uncover a Petrie dish containing nutrient gelatine and expose to the air of the room for from ten to twenty minutes. Then replace the cover and hold it in position with a rubber band. Set aside in a warm (20° to 30° C., 68° to 86° F.), dark place, and watch daily for any change of appearance. (*Figs.* 11 and 12, *pp.* 55-56.)

NOTE.—The nutrient gelatine may be melted and poured into a previously sterilized Petrie dish at the moment of use; but for class purposes certain advantages accrue from having the layer of jelly previously spread. Minute, light-coloured specks will probably show on the surface of the jelly in from thirty-six to forty-eight hours, and will gradually increase in

size. Most of the spots will be hairy or velvety in appearance, but a few shiny, smooth specimens may be observable. The former are due to the growth of moulds; the latter are colonies of bacteria, which are relatively rarely present in air. Liquefaction of the gelatine may also occur as a result of the action of liquefying bacteria; these bacteria play a great part in the biological treatment of sewage, when, by their action, organic, putrescible matter is reduced to inorganic non-putrescible forms.

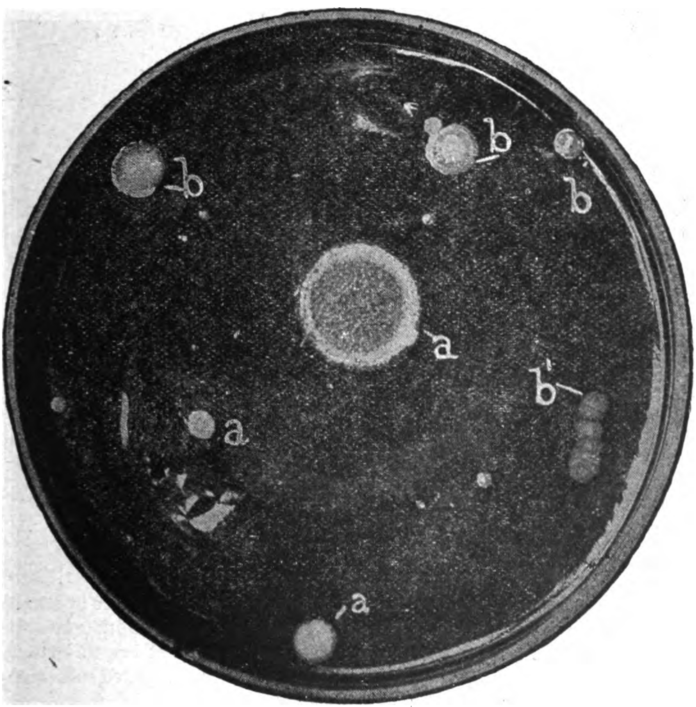

FIG. 11.
a = Colonies of Moulds.
b = Colonies of Bacteria.
b' = Several Colonies developed from Bacteria on a small thread.

(2) Place a few drops of a very weak solution of permanganate of potash (or Condy's fluid) in a tumbler of water, just sufficient to give a faint tint of colour. Breathe into the

water for some minutes through a glass tube, and compare the results, if any, with those of other pupils who have carried out the same process.

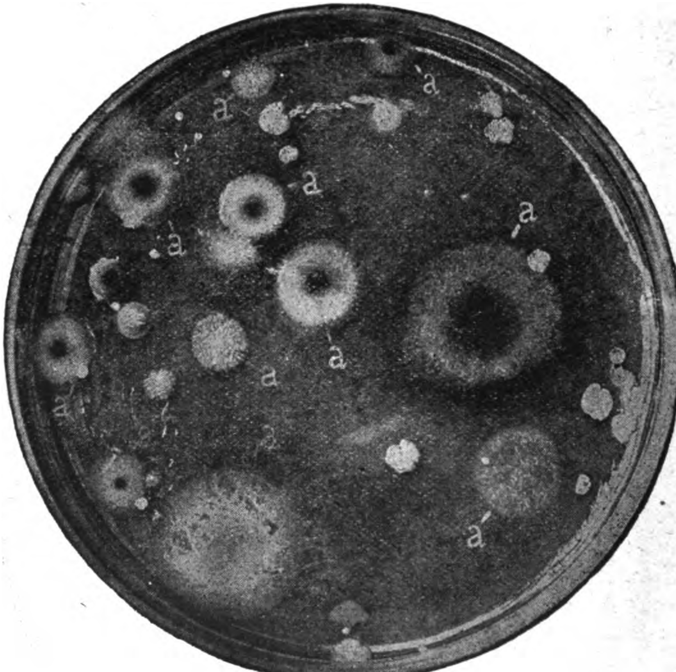

FIG. 12.
a = The principal Colonies of Moulds.*

NOTE.—If the water change colour, it indicates the presence of organic impurity, generally traceable to imperfect teeth or to disordered digestion. In good health, expired breath contains few organic impurities; these are chiefly acquired subsequent to its expulsion from the lungs.

(3) Enclose one finger in a rubber finger-stall for half-an-hour. Remove the finger-stall; rinse it out with a small quantity of the permanganate solution, and pour the rinsings into a test tube. Compare the results with (2).

* *Figs.* 11 and 12 are reproduced here by permission of "The American School of Household Economics," Chicago, U.S.A.

(*C*) *Inorganic Impurities.*

(1) Smear a drop of oil on a glass slide and place outside the window for one hour. Examine the deposit with the naked eye, and, if possible, with a hand lens.

(2) Hold a glass slide in the flame of a candle and note the deposit of soot. Hold a second slide at various distances above the candle flame, and observe the effects of the heated currents of dusty air.

NOTE.—These observations afford an opportunity also for impressing the fact of the increased vitiation of the atmosphere which results in our large towns from imperfect combustion. For instance:—of the 50,000 tons of coal consumed daily in London during the winter months, Sir William T. Thistleton-Dyer has calculated that "six tons of solid matter, consisting of soot and tarry hydro-carbons, are deposited every week on every square mile in and about London."

(*D*) *Excess of Moisture.*

(1) *Combustion.* Hold a clear, cold, dry tumbler over a lighted taper, candle, or gas burner, and observe the evidence of moisture which is soon apparent.

(2) *Respiration.* Breathe on a mirror, or on the back of the hand. Clear evidence is afforded of the presence of moisture in the breath.

NOTE.—Call attention to the chief source, and the undesirable nature, of the moisture which condenses on the glass surfaces of ill-ventilated conveyances and rooms.

(3) *Perspiration* (sensible and insensible). Enclose one finger for half-an-hour in a rubber finger-stall, previously dried inside and out. After removal, examine the inner side of the rubber for evidence of moisture.

NOTE.—These experiments afford opportunity for impressing the fact, often overlooked, that an adult *at rest* gives off daily from the lungs about half a pint of water, and about two pints from the skin.

(*E*) *To Demonstrate the Relation of Dust to Rain and Fog.*

(1) Take a large round-bottomed flask fitted with a rubber stopper, through which pass two lengths of glass

tubing (*a*) and (*b*) which must project into the body of the flask. Connect a short piece of rubber tubing to (*a*) and a longer piece to (*b*). Attach a pinch-cock to each.

Pour sufficient water into the flask, so that when inverted, the neck is rather more than full, and support it in this position. If kept thus for a short time, the air in the flask will be saturated with aqueous vapour. Withdraw a small amount of the contained air by suction through (*a*), thus reducing the atmospheric pressure within the flask.

Observe how this affects the appearance of the contained air. Re-admit about as much air through (*b*) as was withdrawn through (*a*). What follows?

Repeat the two processes several times in succession.

(2) Thoroughly wash the air in the flask by shaking it vigorously for a few minutes. Repeat the experiment of producing and abolishing a partial vacuum in the flask.

Why are the results not similar to those in (1)?

NOTE.—The air is always more or less charged with moisture. Pure water in the gaseous state is transparent; under certain conditions of pressure, temperature, and impurity, this otherwise transparent vapour condenses into cloud and rain. Each particle of solid matter suspended in the air affords a nucleus around which molecules of water assemble; the result of which is to give opacity to the atmosphere. It is believed that the impalpable products of combustion increase this "fogging" power of air, hence the increased tendency to fogs in towns.

Attention must be drawn to the important distinction which exists between the gross palpable dust, which includes soot, familiar as road dust, or in the form in which it is removed by the housemaid's pan and brush, and the ultra microscopic dust to which reference has just been made, which acts as nuclei for the molecules of atmospheric moisture. They are not in the same category.

The above experiment demonstrates very simply the parts played by atmospheric dust in the production of rain and fog. By producing a partial vacuum the temperature of the air contained in the flask is lowered; as the air within is already saturated, condensation of part of this moisture at once occurs, and is apparent by the formation of a distinct haze. The mist instantly disappears when sufficient air is re-admitted to restore the normal atmospheric pressure. So

long as nothing is done to remove the dust from the air the demonstration can be repeated, but if all the dust be washed from the air, as in the second part of the experiment, the moisture is unable to condense, as no nuclei are available. The persistence of fogs in large cities is due mainly to the oily nature of the atmospheric dust; this prevents the evaporation of the mist when a change of atmospheric pressure would otherwise cause its dissipation.

V.—Sources of Purification of the Air.

MATERIALS: *Green shoot; water-cress; candle; taper; splinters; matches; water; potassium chlorate; manganese dioxide; soap; 25% hydrochloric acid; alcohol; ether; cotton-wool; rubber bands.*

APPARATUS: 2 *gas-jars; large glass jar; glass funnel; test tubes; Bunsen burner; hot-air oven; retort stand; several jars; glass plates; large flat rubber cork; thermometer.*

(*A*) *Vegetation.*

(1) Stand two inverted gas-jars, (*a*), (*b*), in an open dish. Place within (*a*) a healthy, green shoot and a small piece of candle; in (*b*) a piece of candle only. Ignite the candles and cover closely with the jars; when the lights are extinguished, surround the jars and their contents with water to the depth of at least an inch, and place them in a sunny window.

After a few days of such exposure, gently tilt the edge of the gas-jar (*a*) and insert a lighted taper, noting the period which elapses before it is extinguished. Repeat with (*b*), and compare the results.

(2) Immerse a small bunch of water-cress in a large glass jar of water, and move it freely about to disentangle the air bubbles. Take a glass funnel, cut off its neck, and lower it into the jar so as to enclose the water-cress. Invert a small test tube full of water over the neck of the funnel, keeping its mouth below the level of the water in the jar. Place the apparatus in a sunny window, and watch for any change which occurs in the course of a few days. When the level of the water in the test tube remains constant, fill a second *very* small test tube with water, and invert it under the water in the jar.

Raise the test tube from the funnel, taking great care not to raise its mouth above the level of the water, and tilt it slowly under the small one.

When the contained gas has been thus collected, prepare a smouldering splinter or match. Then, gently raise the small test tube above the surface of the water, instantly introducing the smouldering splinter. Compare the result with the introduction of a similar splinter into a jar of oxygen gas.

NOTE.—This experiment demands great care to be successful; but if this be exercised it can be carried out with very simple apparatus, and is useful as impressing the purifying influences of green growing vegetation plus sunlight.

(*B*) *Wind.* Close the classroom doors and windows for half-an-hour, while it is in occupation. Leave the room for a few moments, then return; on entering, notice the temperature and odour of the atmosphere.

Set doors and windows open for five minutes, and test the result in the same way by a short absence.

NOTE.—The influence of temperature and of atmospheric pressure on the purification of air can be profitably introduced in connection with lessons in elementary chemistry and physics.

VI.—SOME CHARACTERISTICS OF WATER.

General presence; forms of water; properties and sources of pollution; purification.

TO PREPARE PERMANGANATE OF POTASH SOLUTION. Dissolve one gram of permanganate of potash in 1,000 c.c. distilled water. As a "control test" for colour, take a 250 c c. (8 oz.) stoppered bottle, half fill with distilled water and add the above solution until a rose tint is obtained.

I.—General Presence of Water in Nature.

MATERIALS: *Small pieces of wood and coal; lump of earth; raw, lean meat; milk; egg albumin; bread; cheese; butter; sugar; potato.*

APPARATUS: *Test tubes;* 8 *small china cups; air oven; thermometer.*

(*A*) Heat for a few moments in large, dry, test tubes:—

(*a*) A small piece of wood.
(*b*) A small piece of coal.
(*c*) A small lump of earth.

Observe the indications afforded of the presence of water in these solid substances, being careful to hold the test tubes in such a position that any drops of moisture set free from the various substances tested, shall not run down on to the heated glass. Arrange eight small china cups upon the tray in the air-oven. Place in each small quantities of the following substances:—

Raw meat.	Egg albumin.	Cheese.	Sugar.
Milk.	Bread.	Butter.	Potato.

Replace the lid, and allow a very small flame to play on the under surface until the thermometer marks boiling point. Examine the inside of the air-oven by touch, or by wiping the surface with a piece of tissue paper, for signs of the presence of moisture. Maintain this temperature until no trace of moisture is evident.

Note if, after twenty-four hours, all the moisture appears to be driven out of the contained substances.

NOTE.—Boiling point must be maintained throughout this test, otherwise there is no assurance that all water vapour has been expelled. The thermometer may rise a few degrees above 100°C., as none of the organic compounds will be decomposed at this temperature. Usually, the interior surface of the lid is dry to the touch after two or three hours.

The moist, greasy condition which characterises the milk, butter, and meat, although freed from water vapour, is obviously the result of their fatty nature.

II.—The Three Forms of Water.

MATERIALS: *Tap water; ice; salt.*

APPARATUS: *Small flask; cork; glass tube; thermometer; Bunsen burner; tumbler; test tubes; rubber cork; retort stand; sand-bath.*

(*A*) Place some tap water in a small glass flask.

Insert a cork, through which passes a glass tube bent at

right angles, and a thermometer so placed that the bulb is equally surrounded by the water. Note the temperature.

Set the vessel over a Bunsen burner or spirit lamp.

Observe the changes which occur as the process of heating progresses, and note that, when the larger bubbles which form rise to the surface and burst, the thermometer registers 100° C. Record the point at which steam escapes.

Invert a tumbler over the end of the bent tube. Prove that the steam which escapes from the flask is water.

NOTE.—See that attention is given to the relatively enormous volume of steam produced compared with the small volume of water from which it is generated. Apply the observation to the results in the domestic boiler when the safety valve ceases to act.

(*B*) Take a very small test tube. Fill to the brim with some of the water used in (*A*).

Fit a rubber cork tightly into the tube, and pack it, mouth downwards, in a vessel containing a mixture of ice and salt; then place the whole in a cool spot, and observe the gradual conversion of the liquid water into solid ice.

NOTE.—If this experiment be carefully carried out with a thin-walled test tube, this will burst as the water freezes, and afford an object lesson on the reason why water pipes often burst in frosty weather, and also why the damage is unperceived until the thaw sets in.

III.—Some Properties of Water and Sources of Pollution.

MATERIALS: 15 *grams of salt; lead water* ($\frac{1}{10}$ *grain per gallon*); 10% *bichromate of potash solution; white powdered sugar;* 20 *grams brown sugar; spirits of wine; permanganate of potash solution; dilute hydrochloric acid; tinted water; stamp paper; ice; salt; marble; bottle of soda water; milk, tea, or water; cloth;* 2 *pats of butter; small brick; lumps of sugar; strip of flannel or cotton material; piece of wood; turpentine; lime-water;* 250 *c.c. each of distilled water, hard water, and sewage effluent; cotton-wool;* 3 *equal-sized lumps of chalk; taper; nutrient gelatine.*

APPARATUS: *Flask; rubber cork, with one hole; glass tubes; Nessler glass; test tubes; beaker; small dish; bottle with cork; aspirator; large tray; tall glass-jar with tap near bottom; rubber tubing; pinch-cock;* 3 *glass vessels; pipette; Petrie dish; saucer; earthenware basin; trough; beehive cell; glass nozzle; balance; retort stand; Bunsen burner; sand bath.*

(*A*) *Water Expands with Heat.* Fill a boiling flask with tinted water. Insert a rubber cork, through which passes a glass tube to which is attached a paper scale; a small quantity of water will be forced up the tube. Note the level to which this reaches on the scale. Set on a sand bath above a Bunsen burner, and heat gently. Watch carefully for evidence afforded of the above property of water.

NOTE.—This property of water may also be connected with the provision of safety valves to boilers or to hot-water systems; the open tube serving, in the case of this demonstration, the double purpose of a safety valve, and an index of the expansion which takes place.

(*B*) *Water Contracts with Cold.* Nearly fill a large test tube with water, and mark the level on the tube with a strip of stamp paper. Place the tube in a vessel and pack full of ice and salt. Watch for any changes of level which occur in the water after

(*a*) Ten minutes.
(*b*) Thirty minutes.

NOTE.—Careful observation will enable a record to be made of the contraction which follows the lowering of the temperature of the water to 4°C. (39·2° F.), its *point of maximum density*, and of the expansion which occurs at freezing point, 0° C. (32°F.).

(*C*) *Water Evaporates.* Fill a small open dish with water.

(1) Weigh, and place it in the open air for a few hours. Again weigh the dish with its contents, and compare with the first record.

(2) Fill a bottle with some liquid—milk, tea, or water. Take the temperature of the liquid; cork the bottle, and wrap it in a wet cloth. Set it aside. At the end of an

hour, observe the amount of moisture present in the cloth, and take the temperature of the contents of the bottle.

(3) Take two pats of butter, (*a*) and (*b*). Place (*a*) on a saucer over which a small earthenware basin is inverted. Cover with a wet cloth. Treat (*b*) in the same way, but omit the cloth. Place in the sun, and compare the conditions after 15 minutes.

NOTE.—This property of water and its cooling effects are valuable when applied to purposes of food preservation, or for lowering the body temperature in disease; but serious results to health follow neglect to recognize it when, for instance, clothing is allowed to remain in contact with the body after exposure to wet weather, or after violent exercise.

Some reference should be made, in this connection, to the evaporation which is constantly going on from the surface of the body and the clothing. The different powers of absorption of the various materials used for clothing should also be mentioned, and emphasis laid upon the fact that wool is at the same time the most absorbent of moisture and the worst conductor of heat of any textile fabric; these two properties constituting its great value as a material for clothing.

Another illustration of the importance of bearing in mind this property of water may be drawn from the precautions necessary when a house is closed during the absence from home of a family. The water is liable to evaporate below the level necessary to seal the traps of unused closets, thus allowing direct communication to take place between the drain and the house, and affording free passage to sewer-gas. Such traps should be regularly and frequently flushed, or should be closed before the house is vacated, by being filled on the house side with a mixture of sand and putty, which can be dug out of the pan when the occupants return.

(*D*) *Capillarity of Water*. Weigh a small brick. Place one end of it in a trough containing a little water. Set aside for half-an-hour. Examine, and re-weigh. Repeat this observation with a pile made of lumps of sugar, a strip of flannel or cotton material, a piece of wood, &c.

NOTE.—When solid bodies, which possess pores of perceptible size, are placed in contact with liquids, these capillary phenomena

occur, the liquid being raised upwards against the sides of the solid.

This property of water has to be considered in connection with the methods of hygienic house construction and the character of the materials employed.

(*E*) *Water always Finds its own Level.*

(1) Stand an *aspirator* upon a large tray. Fit a rubber cork into the lower opening through which is inserted a glass tube bent abruptly upwards at right angles. (*Fig.* 13.)

Pour water into the upper opening of the aspirator, and observe how the level of the water is always equal in the large vessel and the glass tube.

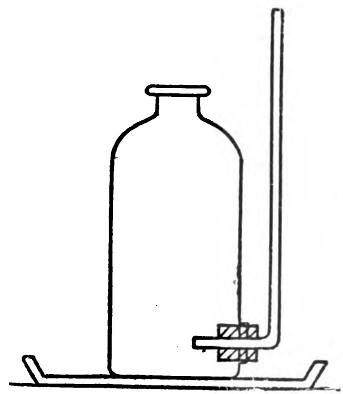

FIG. 13.

(2) Take a tall glass jar with a tap near the bottom. Connect with this tap a long piece of rubber tubing, at the end of which is a narrow glass tube.

Gradually fill the jar with water, but pinch or clip the rubber tubing so that the water does not escape.

When the jar is full, lower or raise the tubing to varying levels, and observe the height to which the jet of water from the tube rises relatively to the water contained in the jar.

NOTE.—By the utilization of this property, water can be, and is, supplied for domestic, sanitary, and commercial purposes under conditions which would otherwise demand the employment of some motive power, as steam, or manual labour, in pumping, &c.

An Artesian well suggests a familiar and obvious illustration, which is well demonstrated by (2).

(*F*) *Water holds Solids in Suspension; Organic and Inorganic.*

(1) Heat a sand-bath thoroughly over a Bunsen burner.

Arrange upon it three glass vessels, (*a*), (*b*), (*c*), each containing 250 c.c. (½ pint) of water as follows:—

(*a*) Distilled water.
(*b*) Hard water.
(*c*) Sewage effluent.

Evaporate the water by gentle heat over a water-bath, then examine the glasses, and compare their appearance.

Apply a drop or two of dilute hydrochloric acid to (*b*), and a similar quantity of a solution of permanganate of potash to (*c*), in order to assist determination of the nature of the residue in each case.

(2) Draw up 1 c.c. of tap water with a sterilized pipette, and drop it into a sterilized Petrie dish. Add a little warm nutrient gelatine. Cover quickly, and mix the fluids by gentle rotation.

Place aside in the dark, at a temperature of 18° to 20°C. (64° to 68° F.), and record the changes which occur during ten days.

NOTE.—Effervescence will follow the application of acid to the lime salts in (*b*), if much be present; if there be but a small amount, solution only will result.

The change of colour in the permanganate solution will afford evidence of the organic nature of the residue in (*c*). Sewage effluent* should be supplied in a fairly clear condition, in order to show that no clue to the presence of serious *invisible* impurities may be afforded by naked eye observation, a lesson which will also be impressed by the test made for the micro-organisms in perfectly clear water. A further lesson is emphasized in connection with the need for more frequent change of water in public baths. The power of water to hold bacteria in suspension seems limitless, and the additions contributed by individual bathers runs into thousands of millions.

(*G*) *Water contains Dissolved Gases.* Compare the appearance of a bottle of soda-water with one of tap water.

(1) Uncork the bottle of soda-water, and notice the bubbles of gas which escape. Hold a lighted taper to the mouth of the bottle, and name the gas which escapes, from

* Suitable samples can usually be obtained through the courtesy of Public Health Officials.

previous knowledge of the effect upon combustion of its presence in large quantities.

(2) Completely fill a flask with tap water (*Fig.* 14). Insert a cork and delivery tube which has been filled with water, dipping the tube under a test tube full of water, inverted over a bee-hive cell in a dish of water. Heat the flask,

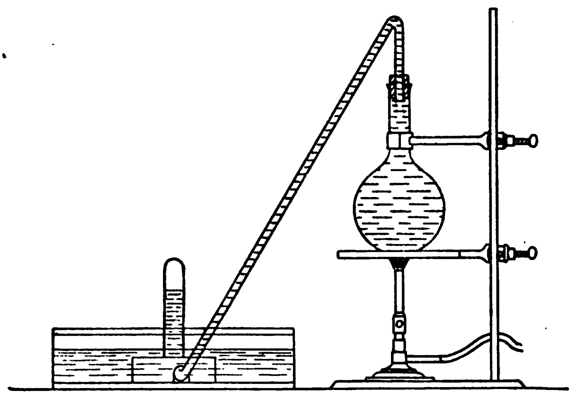

FIG. 14.

and observe that the gases dissolved in the water are driven out and collected in the test tube. Remove the flask and delivery tube, then test the contents of the test tube with:—

(*a*) A little lime-water;
(*b*) A lighted taper;

to show the presence of both carbon dioxide and oxygen.

(*H*) *To illustrate the Heat Capacity of Water.*

(1) Raise 100 c.c. of water in a beaker to a temperature of 80° C. (176° F.) over a Bunsen burner.

Pour this water im ediately into a vessel containing 100 c.c. of water at 0° C. (32° F.) and at once take the temperature. What does the thermometer record?

(2) Raise 100 c.c. of water to the same temperature as in (1) and at once pour it into a vessel containing 100 grams of pounded *ice* at zero; introduce a thermometer; watch the temperature as the ice melts. What temperature is recorded throughout and at the conclusion of the melting process?

NOTE.—The result of the mixing process in (1) will be a temperature of 40° C. (104° F.) whereas in (2) the temperature of the contents of the vessel in which the ice and water are mixed will remain at zero until every particle of ice is melted. This result shows clearly that the change of 100 grams of ice into 100 c.c. of water requires as much heat as will raise 100 c.c. of water through 80° C. (176° F.). This heat represents what is known as the *latent heat of water*, which is greater than that of any other liquid. When every precaution is taken to make sure that as little heat as possible is lost to outside bodies or is gained from them it is found that 1 gram of ice takes 79 calories ("*The Human Body*," II. (*D*), *page* 78) to bring about its change into water, *i.e.*, as much heat is absorbed as would raise the temperature of 1 gram of ice-cold water to 79° C. The number 79 thus defined is the latent heat of water.

Distinguish between heat and temperature. The thermometer indicates the high or low temperature, that is the intensity of heat of a substance, but it gives no clue to the total amount or quantity of heat contained by that substance. This can be measured by means of a calorimeter (*page* 78).

(*I*) *The Solvent Powers of Water.* Fill a small tumbler brimful of water, and drop in some white, powdered sugar gently and gradually.

Observe the quantity of sugar which can be added before the water overflows, and test by taste the general diffusion of the sugar.

(*K*) *On Solids.*

(1) Immerse 20 grams (¾ oz) of brown sugar in 50 c.c. (2 oz.) water. Stir frequently, and observe the results after 15 minutes.

(2) Place two pieces of sugar of the same size in two wide test tubes, (*a*) and (*b*). Fill both test tubes half full of water, taking care that the water is the same height in each.

Shake tube (*a*) vigorously for 5 minutes. Boil the water in (*b*) for the same length of time, and observe the results.

(*L*) *On Liquids.*

Add some spirits of wine to a bottle half full of water. Cork and shake the bottle well. Observe how completely the alcohol mixes with the water.

NOTE.—Methylated spirit in its ordinary form will not answer the purpose for this demonstration. The commercial product sold under this name consists of spirits of wine, to which wood-naphtha, with some petroleum, has been added to the extent of 10% in order to make it unfit for use as a beverage. These added substances would vitiate the experiment, as they render the mixture opaque when combined with water. Petroleum is immiscible with water, forming a cloud of droplets when a combination with water is attempted.

(*M*) *On Gases.*

(1) Take a flask full of water. Of this, pour 25 c.c. (1 oz.) into a test tube, and add a few drops of lime-water. Observe the results, if any.

Make some carbon dioxide acid gas by pouring dilute hydrochloric acid on marble, and let it bubble freely into the flask of water for one minute. Again test 25 c.c. of the water in the flask with lime-water, and compare with above.

(2) Take three equal-sized lumps of chalk, and place them in three gas jars (*a*), (*b*) and (*c*); nearly fill:—

(*a*) With distilled water.
(*b*) With tap water.
(*c*) With water charged with carbonic acid gas.

Carefully compare the results, and notice the increased solvent power of water when highly charged with gas.

NOTE.—The sources of carbon dioxide gas should be recalled, and the results upon water brought into contact with these sources when of an organic character.

The influence of temperature on the solvent power of water is largely employed in cooking processes, both for liquids and solids; as a general rule, the higher the temperature the greater the solvent power.

With gases, the reverse obtains; the solvent power of water for gases decreases with an increase of temperature; thus, if the water in a trap has absorbed sewer gas, and the temperature of the water is raised from any cause, the gases are expelled and dispersed into the surrounding air, a most undesirable result when in a confined space, such as an ordinary house.

(*N*) *On Minerals.* Immerse 15 grams (1 grain) of salt in 50 c.c. (2 oz.) of water. Observe the results after from 10 to 14 mins.

(*O*) *On Metals.* Nearly fill a Nessler glass with some lead-water ($\frac{1}{10}$ gr. per gallon), place on a white ground in a *very good* light.

With a glass rod, add a little bichromate of potash (10% solution freshly made), putting it round the inside of the glass just on a level with the water.

Observe the cloud gradually formed as the bichromate of potash sinks.

Test some tap water in the same way, and observe carefully; comparing the two observations.

NOTE.—To make the lead-water, immerse an inch of lead pipe in water slightly acidulated (by the addition of a few drops of acetic acid) for a few hours before use. It may be advisable to draw attention to this as a common source of pollution under certain circumstances, for instance, where moorland water is the source of supply. It has been found by Houston that in peaty soils certain micro-organisms exist which are capable of producing an acid of the fatty series, and thereby acidifying water which has passed through, or over, the soil.

Water must remain for some time in the pipes to act on the lead; new pipes are more liable to the plumbo-solvent action than old ones, and this action is increased by hot water and by pressure.

A further test is suggestive: immerse a piece of freshly-scraped lead in distilled water, and test with bichromate of potash after 12 hours. The risk attendant on the transit of very "soft" water through lead pipes is thus illustrated. One-twentieth of a grain of lead per gallon is a source of danger to the consumers.

IV.—Methods of Water Purification.

MATERIALS: *Sweetened and coloured water; polluted water; permanganate of potash solution; liquid nutrient gelatine; earth; alum; charcoal; powdered sugar; sand; filter paper.*

APPARATUS: *Würtz flask; 7 flasks; basin; sand bath; Bunsen burner; tripod; retort stand; 2 covered vessels; colander; 2 Petrie dishes; pipette; tumbler; 2 glass funnels.*

(*A*) *By Distillation.*

Arrange and support a Würtz flask half filled with sweetened and coloured water over a Bunsen burner, with

the long tube passed into the neck of a small flask. Place the receiving flask in a basin of cold water, and cover it with wet filter-paper. (*Fig.* 15.)

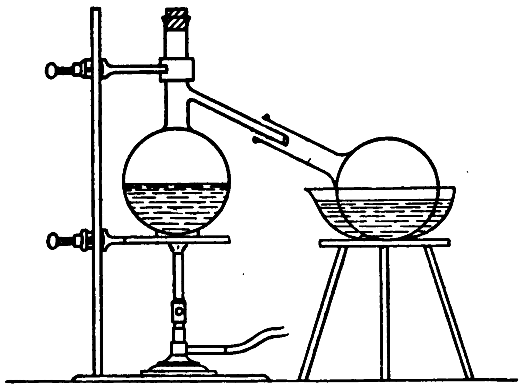

FIG. 15.

Carefully boil the water in the Würtz flask. Throw away the first water condensed; then collect a small quantity, and compare it with that contained in the flask, noting any evidence afforded of purification.

(*B*) *By Boiling.*

(1) Take two flasks, (*a*) and (*b*). Half fill each with polluted water, taken from a stagnant pool or puddle in the road. Boil (*a*) for half an hour, cool and transfer the supernatant water to a clean flask. Add permanganate of potash solution to both flasks until they assume a rose-pink colour. Keep both at a temperature of 25°C. (77°F.) for an hour. Compare results.

NOTE.—It is allowable to use permanganate of potash for this demonstration; but the caution must be given that this salt parts readily with its oxygen to every form of organic pollution, vegetable and animal. It does not therefore afford a reliable index (except under somewhat elaborate conditions) of the nature or extent of water pollution.

(2) Boil some water in a covered vessel for 20 minutes. Cool, and taste. Re-aerate the remainder by pouring from

one vessel to another, (preferably through a colander), for a few minutes, and observe the result on taste.

Prepare two Petrie dishes (*a*) and (*b*). Pour into each a small quantity of liquid nutrient gelatine. To (*a*) add a few drops of tap water, and mix thoroughly with the gelatine by gentle rotation. Add to (*b*) a similar quantity of water boiled for 20 minutes in a covered vessel, cooled without removal of the cover, and then carefully transferred to the sterilized Petrie dish by means of a sterilized pipette. Set aside in a dark place, at a temperature of about 19°C. (66°F.) for subsequent observation.

(*C*) *By Precipitation.*

Mix some earth and water in a tumbler, add a few grains of alum; stir, and stand aside for observation later on.

NOTE.—This method of purification deals primarily with turbidity. A coagulent, such as lime or alum, forms an inorganic precipitate in the water, the presence of which causes an aggregation to take place of the fine particles in suspension, including bacteria, and allows them to be more easily removed by filtration than would otherwise be the case. In addition, the alumina has a chemical affinity for dissolved organic matter, and it promotes more complete purification when the process precedes filtration through sand and gravel, as is the case in public water supplies.

(*D*) *By Filtration.*

(1) Stir a little charcoal or pulverised earth into some water until turbid. Line a glass funnel with double filter paper. Support it over a glass vessel, and gently pass the mixture through the filter.

Examine the product, and record the results of this treatment.

(2) Mix some powdered sugar with a little charcoal, earth, or sand. Stir well in water.

Line a glass funnel with double filter paper as above, and support over a glass vessel.

Fill gently with the liquid; when the filtration is complete, observe, and taste the results.

NOTE.—It is important to impress the fact that ordinary methods of domestic filtration are worse than useless as a means of purification or protection. Some evidence in proof of this statement is afforded by these experiments.

The first illustrates the *mechanical* action of a filter, for substances that are larger than the pores of the paper will not pass through.

The second demonstrates that though *suspended* matters may be thus separated, *dissolved* matters pass through.

Any further references to the pollution of water than those implied in the various illustrations of its properties are purposely omitted.

The detection of *impurities* demands tests of a most delicate nature, chemical, microscopical, bacteriological, and observational. It is quite impossible for these to be employed by persons other than experts; any attempt to do so gives rise only to a sense of false security.

Scientific accuracy and prudence therefore dictate that no pretence should be made to treat so complex and intricate a process in an elementary way, or to suggest the inference that domestic tests have any value.

As the character of water, whether *hard* or *soft*, is of economic rather than hygienic importance, this part of the subject is dealt with under the head of "Clothing."

PART II.

VII.—THE HUMAN BODY.

GENERAL SURVEY.

External survey. Observations on characteristics of life. Plan of body and general structure. The systems of the body and their functions.

I.—External Survey.

(*A*) Observe the *chief divisions* of the human body, *viz.*, into *head*, *trunk*, and *limbs*.

(*B*) Notice the *erect position*, characteristic of human beings, and the advantages thus derived—*e.g.*, wider range of vision; control of the fore limbs, which are freed from the necessity to act as supports to the trunk; and power to employ the arms and hands in multifarious ways.

(*C*) Notice some of the features associated with the erect position which distinguishes man from other animal species:—

(1) The position of the eyes and ears, and the provision for the shelter of the former.

(2) The width of the shoulders and chest, and the shape of the collar bones, compared, *e.g.*, with the merrythought of a bird.

(3) The strong pelvis and thighs.

(4) The relatively large feet, which form a firm base for the body in its erect position.

(5) The supple, pliable, sensitive hands and fingers, constituting the most perfect known instrument.

(6) The position of the nose, which serves as a "sanitary scout."

NOTE.—It is of interest to institute a comparison between the hand and foot, and to point out the different functions they serve, though the toes and fingers correspond in number, and,

roughly, in structure. The small wrist-bones permit of very free movement; the long, slender bones of the fingers give a large grasp and permit of delicately adjusted movements. The thumb, opposed to the fingers, is an essentially human characteristic. The hand can be used as a powerful or most delicate instrument; it is capable of rapid motion or of sustained endurance; it can be now flexible, now rigid. The ankle, on the contrary, is made rather for strength than for free movement, as are all the short, thick, hollow bones of the foot, to support weight being their primary object.

(*D*) Observe the *distribution* of the bones so far as these can be detected by external examination:—

(1) The case of bone (*the skull*), which encloses the delicate brain, injury to which threatens life, as the brain is a vital organ.

(2) The vertebral column (*the spine*), which protects the spinal cord, serves as an axis for the general support of the trunk, and, by its perfect articulation, permits of free movement.

(3) The seat-bones (*the pelvis*), which support the internal organs and afford a "fixed point" to the spine.

(4) The light cage (*the thorax*), formed by ribs, shoulder-blades and breast-bone, in which are enclosed the heart and lungs. Protection is thus provided for these vital organs.

(5) The plan of structure common to the four *limbs*, each jointed in three places, their flexible extremities, the range of motion possible in the several joints, with the advantages thus afforded in the fulfilment of the functions and activities of daily life.

(*E*) Notice some further *characteristics* peculiar to Man:—

(1) The large proportion of the skull occupied by the brain, and the relatively small face.

(2) The small jaw and peculiar form of mouth adapted to speech rather than to constant mastication, (*cf.*, the ox, sheep, or horse).

(3) The great power of expression possessed by the muscles of the face.

(4) The restriction of hairy surface chiefly to the head, and the beauty of the elastic supple skin.

(*F*) Study so far as possible the mechanism of the body's movements from outward observation. Observe the signs of *ceaseless movement* during life.

Endeavour to feel the attachments of the straps of contractile flesh, or muscles, to the bones (*e.g.*, of the arms), and observe their method of action. Notice the strength of the muscles which support and protect the abdomen, yet allow considerable freedom of movement (stooping, for example), and at the same time supply an elastic case for the digestive and pelvic organs, of which the size is a constantly varying quantity.

Test the sensations experienced and the impressions received upon lightly clasping a muscle (*e.g.*, in the upper arm), (*a*) when active, (*b*) when at rest.

Compare the control which can be exercised over the movements of the head, trunk and limbs with, say, efforts to hold the breath or to stop the heart's beat.

(*G*) Note the *warmth* of the body; record observations upon the appearance of the skin when warm and when cold, and the conditions by which these appearances are brought about.

(*H*) Test the *sense of touch* possessed by the skin in various parts of the body, and observe how the sensitive finger tips are protected and supported by the horny nails. (Ch. XII., *pp.* 208-12.)

II.—**Observations on the Characteristics of Life manifested by the Human Body.** (*cf.* III. "THE CHARACTERISTICS OF LIFE," *pp.* 20—37.)

(*A*) *Metabolism.*

(1) *Absorption.* That nutritive substances are absorbed is proved by :—

(*a*) The sensations of reinvigoration after the digestion of suitable food.

(*b*) The sensation of diffused warmth when hot fluid has been drunk, or of general relief when thirst is alleviated.

(*c*) The changed form in which food stuffs are excreted when digestion is good, their nutritive ingredients having disappeared during their passage through the alimentary canal.

(*d*) The pallor, loss of weight and exhaustion when food is withheld; the stunted growth where food is deficient or defective; the converse of (*a*) and (*b*) when hunger and thirst are not appeased.

(2) *Excretion.* That the residue of food stuffs and the various secretions of the body are excreted is shown by:—

(*a*) The daily excretion of solid residue by the bowels and of fluid (*urine*) by the kidneys.

(*b*) The sweat which is excreted by the skin as visible or invisible perspiration.

(*c*) The increase of moisture, warmth and carbon dioxide gas present in expired air. (*cf.* III. "The Characteristics of Life," "Respiration," V. (*A*), (*B*), and VIII. (*A*), *pp.* 27—32.)

(*B*) *Sensibility or Irritability.*

Mention numerous illustrations of this characteristic; *i.e.*, of response to stimuli received through sensations of sight, sound, touch and so forth (*e.g.*, laughter, when tickled); the movements which express pleasure or pain from the applications of agreeable or excessive heat or cold, or from pressure or exercise; the desire to imitate the actions of others in play; consumption of food or drink from a sense of hunger or thirst, etc., etc.

Note.—The evidences of response to stimulus can be further illustrated by comparison of the appearance of those who live under good conditions of food, warmth, light, air, housing, exercise and rest, with that of the poor and neglected; or by observations on very little children brought up among intelligent surroundings or the reverse; the former talk, are more alert and intelligent, while the latter are usually dull and backward.

(*C*) *Movement.*

Note all the movements of the body, to be discovered by external observations, which continue throughout life.

NOTE.—The beat of the heart; respiratory movements; blinking of the eyelids, etc.

(*D*) *Energy and Heat Production.*

MATERIALS: *Sheet of cotton wool; ice.*

APPARATUS: *Bright tin pot; glass c.c. measure.*

To prove that the body produces heat, measure, as follows, the amount given off by two fingers during five minutes (1) after a period of sedentary occupation, (2) after very active exercise.

Take a *bright* tin pot and surround it with a sheet of cotton-wool; this will then serve as a simple *Calorimeter.* Place a lump of ice in the pot, introduce two fingers of the left hand, but do not touch the ice. With the disengaged hand tuck the cotton-wool lightly but thoroughly over the mouth of the pot and round the wrist in order to keep in the heat.

After five minutes withdraw the fingers, together with any unmelted ice, and measure the amount of water in the pot. Record the quantity in cubic centimetres. Then calculate the amount of heat given off by the fingers during the five minutes. 80 calories of heat are necessary to melt 1 gram of ice.

NOTE.—The standard measure of heat is termed a *calorie;* it represents the quantity of heat necessary to raise 1 gram of water through 1°C. This must not be confused with the large or kilo calorie, *i.e.*, the amount of heat required to raise 1 kilo, the equivalent of 1 litre ($1\frac{3}{4}$ pints) of water 1°C., or 1 pound of water 4°F. The kilo-calorie is very usually employed for measuring the heat value of foods, and is spelt with a capital C. In the case of strictly scientific observations precautions are taken that the water employed in the tests should always be raised from a temperature of 15° to 16°C. (59° to 61°F.), because the quantity of heat required to raise any given volume of water to a higher temperature varies slightly with the temperature of the water when the experiment is begun.

The adoption of this standard temperature consequently ensures correspondence in comparative tests.

This experiment represents, on a small scale, the method by which the amount of heat produced by a man's body in an hour is scientifically determined.

The temperature of the human body can only vary within very small limits without causing death, *i.e.*, between 35° and 45°C. (95° and 113°F.). The temperature is kept uniform by the nervous system controlling heat production in the tissues and heat loss, chiefly by the skin; artificial aid is derived from food and clothing.

(*E*) *Heredity, Growth, Reproduction, and Adaptability.*

Attention can be called to the activity of each of these life characteristics in mankind. They should be emphasized to a greater or less degree and dealt with in more or less detail according to the age, social position, sex and general development of the pupils.

NOTE.—Most children are interested in observing the very different proportions which exist between the parts of an infant's body and those of an adult. For example: in most very young children the following points are distinctly noticeable:—

(1) The very large head and relatively small face.
(2) The long body and prominent abdomen.
(3) The short limbs and almost useless hands.
(4) The narrow chest and undeveloped muscles.
(5) The absence of hair and teeth.

With older girls it is especially useful to emphasize these evidences of an immature phase of existence, and observation can be directed to the gradual development of intelligence, motor ability and independence during childhood. Their interest may be also advantageously directed to some of the reasons why this period of immaturity is so much longer in human beings than it is in the case of familiar animals; *e.g.*, infancy is associated with increased possibilities of mental growth and educability, though this capacity for development in childhood is often prejudiced by adverse conditions.

Further, the opportunity is afforded for reference:—

(*a*) To evidence of the transmission of good physical and mental qualities in the families of historical characters, or of contemporary notabilities.

(*b*) To the long period during which growth in height continues, about 20—25 years, and of the much longer persistence of growth in bulk.

(*c*) To the responsibilities associated with the power to transmit to others, and continue in them, the property of life; as well as the influence of good homes on the health of the nation.

(*d*) To the wonderful adaptability by which mankind finds it possible to live in extremes of climate under conditions of great hardship and on very varied forms of food. Encourage the collection of observations among the older pupils as to evidences of adaptation to environment among the peoples of the world in respect of stature, clothing, diet, occupations, recreations, etc., and interest them in a search for illustrations of this power drawn from history.

III.—Plan of the Body.

MATERIALS: *Freshly killed young rabbit; strong pins; drawing pins; water.*

APPARATUS: *Dissecting board; set of dissecting instruments (scissors, scalpel, knife, forceps, needles); good hand lens; 2 lengths stout yet flexible wire; about 20 cms. glass tube; basin.*

(*A*) Take a freshly-killed, unskinned, young wild rabbit. Compare the general plan of the animal's body with that of a human being, by repeating on the rabbit the external examination made in I. (*A*), (*B*), (*C*), (*D*), (*E*).

NOTE.—*Throughout this Section the dissections should be compared with the illustrations of corresponding parts in the human body shown in the text.*

(*B*) Lay the rabbit on its back, and fasten it down to the dissecting board by strong pins through the limbs.

(1) Open the mouth; examine the teeth; classify them as *incisors* (cutting), *canine* (tearing) and *molars* (grinding) (*Fig.* 16). Distinguish the different parts of the mouth and throat; the roof or hard palate; the tongue; and the positions of the air and food passages. For this latter purpose, pass (*a*) a piece of soft, flexible wire through one nostril—it will appear in the *pharynx*; and (*b*) a similar soft, *bent* probe

down the back of the throat into the gullet. (This can only be carried out at the expense of some care and trouble). Look carefully on the sides of the pharynx, or throat-cavity, for the small openings into the *Eustachian tubes*; pass a bristle along one of these tubes into the middle ear-cavity, with which it communicates.

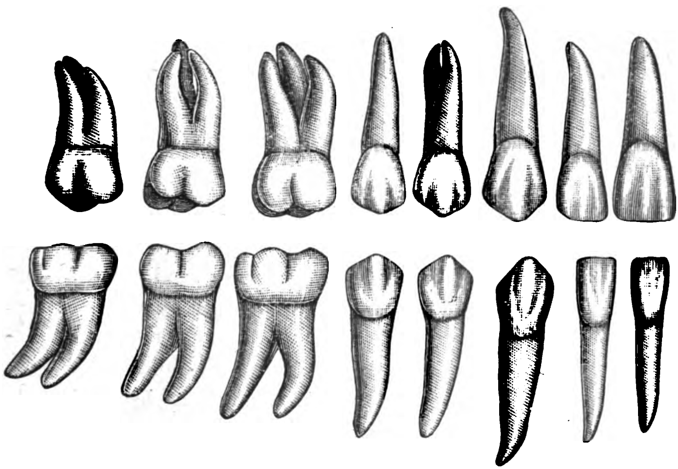

FIG. 16.—Adult Human Teeth.

(2) Cut through the fur and skin, along the middle line from the chin to the bottom of the breast-bone (*sternum*). This can be most successfully accomplished by raising the skin over the sternum with the forceps and making a small, shallow incision. Insert the points of the scissors and cut upwards, continuing to raise the skin in advance of the scissors, a precaution which should prevent injury to the muscles beneath. Pull the skin apart, and notice the layer of neck muscles beneath, enclosed in their glistening sheaths of connective tissue. Separate these, in order to find the white, cartilaginous rings of the windpipe (*trachea*).

(3) Continue to divide the fur and skin from the breast-bone throughout the whole length of the body to the pubis,

being most careful not to cut into the structures beneath. Then start from the median incision, about the middle of the animal, and make transverse incisions through the skin nearly round to the spine; lay back the flaps of skin, and fasten them to the board with drawing pins.

Notice the division of the trunk by a large, circular muscle, the *diaphragm*, into two large cavities, the thoracic and the abdominal; and make what observations are possible upon the contents of the cavities before separating the muscles.

(4) Take the windpipe between the finger and thumb; make a small incision, and gently pass probes upwards into the mouth and downwards into the lungs, in order to prove its connections with these parts. Insert one blade of the scissors in this small incision and slit up the windpipe; open it up and examine the larynx; find, at the root of the tongue, the flap (the *epiglottis*) which guards the larynx from the entrance of other than gaseous substances.

(5) Before opening the cavity of the chest or thorax to examine the heart and lungs, look at the breast bone and the attached ribs. Trace these back to the spine. Observe if they are of similar substance throughout, or if, and where, bone is replaced by gristle or cartilage.

(6) To examine the *thorax* and its contents the anterior wall must be removed in one piece. Great care is necessary to avoid injury to the organs and vessels beneath; therefore the directions must be followed with extreme accuracy.

Make a transverse incision just in front of the diaphragm and then cut through the ribs along each side, lifting away the triangular piece of sternum and ribs. By this method the following parts can be examined *in situ*:—

(*a*) The *thymus gland*.

(*b*) The heart enclosed in its serous membrane, the *pericardium*.

(*c*) The lungs also enclosed in a serous membrane, the *pleura*.

(d) The diaphragm pierced by the gullet (*œsophagus*) and the large blood vessels which supply the trunk and lower limbs.

(e) The trachea, and its division into the two large bronchial tubes, the *bronchi*. For this purpose it will be necessary to remove the thymus gland, which is large in the rabbit and covers the junction of the windpipe with the bronchial tubes.

(f) The *thyroid gland* lying on the sides of the trachea.

(7) Pass a glass tube down the windpipe towards the lungs and blow in steadily. Note the elasticity of the lungs and their power of distension; also the collapse which follows when the air is expelled or the supply ceases.

(8) Carefully mop away any congealed blood at the base of the heart and at the roots of the great blood vessels. Then examine the heart, but first slit up the pericardium and observe its delicate structure.

Identify the several parts of the heart, as the right and left *auricles* and the right and left *ventricles*; and carefully distinguish any external differences to be detected in their colour, appearance or texture.

(9) Find the three great blood-vessels:—

(a) The *aorta*.
(b) The *superior vena cava*.
(c) The *inferior vena cava*.

Trace their courses and branches; ascertain also where they enter or leave the heart, and whether or no they pierce the diaphragm.

(10) Remove the heart and lungs carefully from the body and separate them from each other. Then take the heart and open its cavities; note the position and structure of the valves, and the partition (*septum*) between the two sides of the heart.

(11) Examine the dome-shaped diaphragm, and note the transparent, fibrous centre of the muscle and its fleshy sides and back. Observe the points where the aorta, inferior

vena cava and gullet pass through into the abdomen, and the two muscular pillars by which the diaphragm is attached to the spine.

(12) Take the lungs and trace the windpipe as it divides into the bronchial tubes. Place the lungs in a basin of water and observe that they float, in consequence of the large amount of contained air in their light, porous, spongy substance.

(13) Examine the abdomen. Carefully divide the layer of strong, fibrous muscles which support and enclose the abdomen, by nipping up a portion of the muscular layer with the forceps, and very gently inserting the scissors, directing the points upwards, in order not to injure the mesentery. Or, the muscles may be firmly stretched apart by the thumb and fingers of the left hand, while they are cautiously cut with a sharp penknife or scalpel.

Identify the organs thus exposed, and make notes on their position, shape, colour, and parts:—

(*a*) The liver, a dark-red mass, divided into several lobes, with the gall-bladder, full of green gall, or bile, attached to its underside.

Endeavour to trace the common bile duct passing from these two organs to the small intestine.

(*b*) The stomach, a large, whitish bag, partly covered by the liver, and probably more or less distended with food. Observe where the gullet (œsophagus) enters the stomach, and consider the reason why this is called the "cardiac" orifice. Find the pyloric orifice, or opening between the stomach and the small intestine.

(*c*) To examine the small intestine, gently raise a coil and observe the very delicate and transparent membrane (the *mesentery*) by which it is suspended; trace in this the arteries and veins. If the animal has been recently fed, a third set of thread-like tubes, the lacteals, can also be observed. They will

be white from the chyle with which they are filled during the process of digestion. Chyle is a milk-white fatty fluid absorbed by the lacteals from the small intestine by means of the villi. Find the portal vein by tracing its course from the walls of the stomach and intestines to the liver. Note that the *duodenum*, which is the loop of intestine that joins the stomach, is more firmly fixed by this supporting membrane than are the rest of the coils. The thin, irregular, whitish masses scattered in this portion of the mesentery form the *pancreas*; they are easily overlooked, especially if the mesentery has been much disturbed (*Fig.* 17).

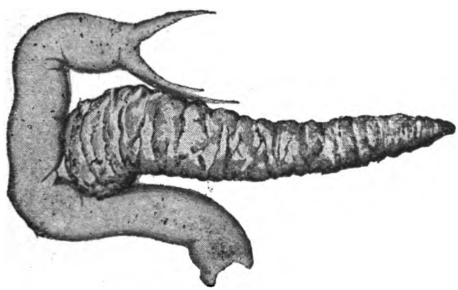

FIG. 17.

(*d*) Observe that the large intestine is composed of three parts; the *cæcum*, the *colon* and the *rectum*.

(*e*) Turn the alimentary canal over and thus

(1) Expose the spleen, a small, dark-red organ just below the stomach.

(2) Expose the kidneys, which lie on, and are attached to, the dorsal wall of the abdomen. The right kidney is just behind the liver, and the left one about 4 cms. ($1\frac{1}{2}$ in.) lower down; notice also the *adrenal bodies*, or supra-renal capsules—small organs just above each kidney.

(3) Notice the *ureters*, two slender tubes passing backwards from the kidneys along the dorsal wall of the abdomen, very near the middle line. At the hinder end of the abdomen they bend inwards and open into the bladder (*Fig.* 18).

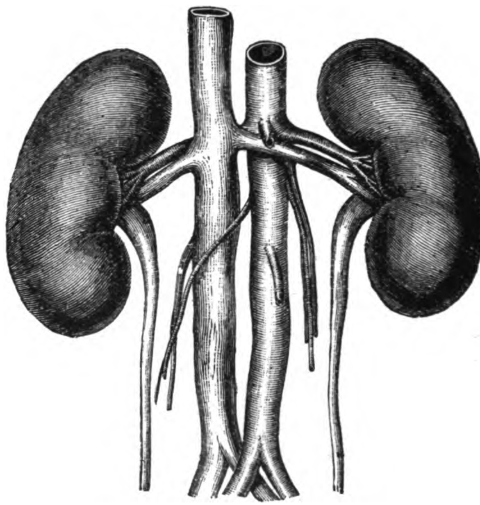

FIG. 18.

(4) The bladder is a thin-walled, muscular sac, most of which lies behind the *symphysis pubis*, *i.e.*, the articulation between the pubic bones. The bladder terminates in a straight tube, the *urethra*.

(5) Trace the course of the urethra, which passes between the *symphysis pubis* and the rectum, and follow it to its external opening on the posterior surface of the animal.

(*f*) Carefully cut through the mesentery with scissors along the whole length of its attachment to the intestines, except at the first portion, or duodenum. Lay out the gut on the board, and identify the stomach, duodenum, jejunum, ileum, cæcum, colon,

and rectum, which together constitute what is known as the alimentary canal. Observe how the small intestine opens into the side of the large intestine, leaving one end, the cæcum, free in the body cavity. (This part is much larger in the

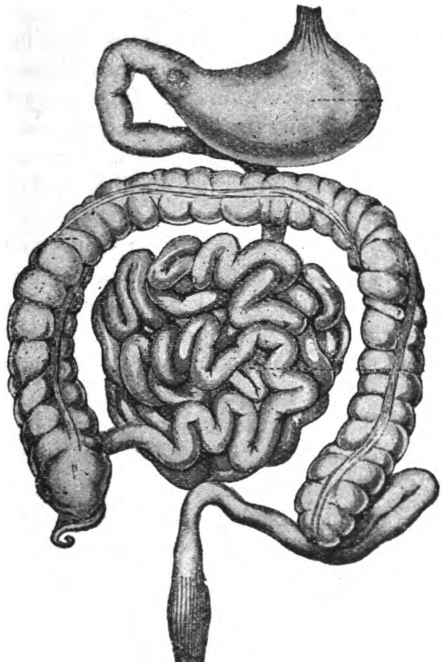

Fig. 19.

rabbit than in man). Find the *vermiform appendix*, or small tube which opens from one end of the *cæcum* (*Fig.* 19).

(*g*) Examine the internal structure of the stomach and parts of the intestines *under water*. Slit up portions of the intestines, remove the contents and study the lining membranes. Notice the gradual change in the consistence and character of the fæces between

the upper and lower end (the *anus*) of the large intestine.

(1) Examine the stomach, and look carefully for the shallow pits, or openings of the gastric glands which can be seen with a strong magnifying glass.

(2) Examine the small intestine. The *villi*, small conical elevations, can be detected with a good hand lens upon the surface of the soft, shiny mucous membrane. They may be compared with the rubber mats in common use on the counters of shops for the purpose of depositing change, which are closely set with small conical elevations; if rolled into a cylinder these mats would give a rough idea of the structure of the mucous membrane of the small intestine. The *valvulæ conniventes*, irregular folds running *round* the intestine, may also be similarly observed; their function is to increase the surface of the mucous membrane of the intestine.

(3) Compare the muscular and mucus coats of the large intestine with those of the small intestine by observations conducted with equal care.

(*h*) Remove a kidney from the body, divide it in half longitudinally with a sharp cut, and observe the appearance of its parts:—

(1) The *cortex*, or dark granular outer layer.

(2) The *medulla*, formed of the conical processes or *pyramids*.

(3) The *pelvis*, or funnel-shaped bag lined with whitish mucous membrane, into which the ureter dilates.

(14) Examine a limb.

(*a*) Separate a hind leg from the rabbit and remove the skin with the fur. Notice the sheath of delicate connective tissue which surrounds the whole limb; divide this membrane with a penknife or scalpel and, with the aid of forceps, lay it back from the

flesh of the limb. Observe that the flesh is separated into bundles of various sizes and shapes, *i.e.* muscles, each of which is enclosed in its own sheath and attached to its neighbours by similar membranes.

(*b*) Gently separate one of these muscles and, if possible, isolate it throughout its entire length; observe the changes in its shape and structure where it is attached to bone and the mode of insertion; also the result (upon the limb) of its contraction or relaxation.

(*c*) Remove the muscle and cut it across at the thickest part. Find out the details of its structure by careful examination, assisted by a good hand-lens. Compare your observations on its structure with two small pieces of meat, one raw, the other "boiled to rags."

(15) Examine a joint.

(*a*) Remove the skin and fur from the hind leg still attached to the animal's body, and make a careful study of a joint. Move the limb, and observe in which direction and to what extent it rotates with ease.

(*b*) Cut cautiously through the delicate membrane which encloses the joint, and separate the *capsular ligament* which extends all round it and binds the bones together. Note how the tendons attach the muscles to the bones, and compare their appearance with that of the ligaments. Observe that the *synovial fluid*, secreted by the synovial membrane, escapes as soon as the capsular ligament is cut; how does it feel when rubbed between the fingers?

(*c*) Examine the ball or head of the long bone; the cavity, or *acetabulum*, into which it fits; and the round ligament which passes from the acetabulum to the ball.

(*d*) Notice the cartilage, and compare its texture, elasticity, and other properties with those of bone and tendon.

(16) Examine the nervous system.

(*a*) Separate the muscles at the back of the rabbit's thigh, and find a fine, strong, white cord, the *sciatic* nerve. Follow this carefully right up to where it issues by a series of roots from the spinal canal, removing any tissues that may be necessary for this purpose. Complete the observation by tracing the nerve downwards to where its branches terminate in the several muscles of the leg.

(*b*) Take the trunk of the rabbit and examine the spine behind the kidneys and thence upwards towards the head. Close to the dorsal surface and close along each side of the vertebræ will be found two chains of pigmented *ganglia*, or small groups of nerve cells. These are the ganglia of the sympathetic nervous system. Trace the small nerve fibres which run transversely from these ganglia to the spinal nerves; they can most easily be detected behind the kidneys. Other fibres are distributed to the organs of circulation, digestion and excretion.

Remove the skin from the fore limb and find in the *axilla* (the armpit) a network of similar white threads, which disperse as they enter the muscles of the fore limb; this is known as a *plexus* of nerves.

(*c*) Examine the central nervous system. To do this the top of the *cranium*, or bony roof of the skull, must be cut away with a strong and very sharp pair of scissors. Observe:—

(1) The *cerebrum*, or great brain. Remove the fibrous membrane, or *dura mater*, and note the division of the cerebrum into two cerebral hemispheres.

(2) Expose the spine by cutting away the muscles along its whole length; while doing so, examine the arrangement by which the ligaments bind the vertebræ together, holding them in place and yet permitting a certain freedom of movement.

(3) Scoop out the cerebrum and examine the skull. Cut away the bone at the base of the skull, the *occiput*, in order to see the lesser brain, or *cerebellum*; the top of the spinal canal will also come into view.

(4) Cut the roof of this canal away by inserting one blade of the scissors within it; when this is removed the white spinal cord becomes visible. By pulling gently on this with a pair of forceps the connection of the spinal nerves with the spinal cord, as they pass out to the body on each side of the spine, can be detected.

(5) Continue carefully to cut away the roof of the spinal canal until its termination in the *cauda equina* is reached.

NOTE.—The whole of the observations here detailed can be made very satisfactorily with the assistance of a sharp penknife or scalpel, a pair of dissecting scissors, and a pair of forceps (these latter the pupil should be trained to use instead of his fingers), a board or stout piece of mill-board, a good hand-lens, two pieces of stout yet flexible wire, and a soup plate or shallow dish for water.

Were so detailed a dissection to be carried out by each pupil, a considerable number of lessons would be absorbed, especially as many additional details (here omitted for want of space), would suggest themselves to teachers of experience. Where "cold storage" is available (as is now frequently the case in large towns, through the courtesy of tradesmen), a dissection can be kept in excellent condition over almost any period of time; and can be continued at intervals to maintain the interest, or to suit the needs or convenience, of the class. In country districts the supply of rabbits is usually ample, and the cost so nominal that it enables this question of expense to be disregarded. Some of the above observations are obviously adapted for older and much more advanced

students than are others. But, in all cases where it is desired to begin even the most elementary study of physiology in relation to the principles of hygiene, practical acquaintance must be made with the structure and tissues of the animal body by some such means, if its complexity, delicacy of detail and marvellous formation are to be intelligently apprehended. Very inaccurate conceptions of relative positions and proportions are formed by the young and ignorant from even the most carefully prepared diagrams; while papier mâché models mislead those who cannot institute comparisons between the solidity and texture of the organs so represented, with the semi-fluid, often transparent, pliable, fragile, elastic, closely-knit tissues of which they are actually composed. For these reasons fresh specimens of the parts dealt with should always be employed when teaching either structure or function. It may be well, in the case of young girls, to make a preliminary demonstration on a very carefully prepared dissection, in order to avoid arousing sensations of repulsion or disgust, and only to require by degrees that every detailed observation be carried out by each pupil.

Where, however, interest in the subject has been fostered, and a vivid, rational curiosity has been awakened in the processes and functions of life, so that pupils desire to make a personal acquaintance with structures and properties previously described, no objection to handle specimens and no dislike to practical work has been met with, in an experience extending over a long period of time.

The order adopted in the following more extended study of the chief systems of the body differs slightly from that usually pursued, in that a general review of the nervous system precedes consideration of the organs of circulation, respiration, etc. It was first tested, on the advice of Prof. Sherrington, F.R.S., &c., and its advantages quickly became apparent.

All functions, such as the mechanism of respiration, the circulation of the blood by the heart, or the process of digestion, depend for their performance on nervous impulse and control; it is, therefore, almost impossible intelligently to apprehend either functions or movements until this intimate relation is more or less realized, and the unifying influence of the nervous system upon the vital functions is partially understood. At the present time, also, the results of the concentrated work of expert physiologists upon the nervous system, which has extended over many years, enables

more definite instruction to be given upon its structure and functions than is possible in the case, for instance, of the process of digestion and food absorption.

Again, the healthy activity and educational development of the nervous system and its work come more within the sphere or control of personal influence and training than do those systems of the body governed more entirely by the sympathetic or involuntary system. From the hygienic standpoint, therefore, a general conception of the nervous system is of primary importance, and should be assigned a prominent position in any, however elementary, series of lessons on the structure of the body to children over twelve years of age. A study of the sense-organs, in detail, does not come into review until a later period of the Course; the preliminary survey of the nervous system being confined to its general aspects and functions.

VIII.—THE SYSTEMS OF THE BODY AND THEIR FUNCTIONS.

(A) THE NERVOUS SYSTEM (1).

Voluntary and involuntary nerves. Control of movements by nerves. Information derived from sensory and motor nerves. Reflex action. Inhibition. Nerve reaction and skill. The relative nature of sensations. Influence of judgment and experience.

NOTE.—Method of preparing sheeps' brains and spinal cords for purposes of observation.

Immerse the specimens in the following mixture to harden them :—

Potassium bichromate	10 grams.
Formalin	15 to 20 c.c.
Water	500 c.c.

Allow them to remain in the liquid for a fortnight; then remove, and wash in running water for two or three hours. If the brains are not sufficiently hard, they should be soaked for 12 or 15 hours in a mixture of 350 c.c. of 5% formalin and 150 c.c. of 95% alcohol.

In the case of sheeps' brains, careful supervision is usually desirable to ensure that the soft mass receives no injury when the skull is removed. It is a wise precaution to have a suitable vessel ready for their immediate reception, with a supply of

cotton-wool soaked in the bichromate mixture, with which to support the mass when placed in the basin, otherwise they are liable to lose their shape or to be so injured as to be useless.

The potassium bichromate colours the cellular grey tissue (*nerve cells*), but has no effect on the white tissue (*nerve fibres*).

The spinal cord of an ox can be easily procured from a butcher, if he be asked for the *marrow* out of the spine. It can be divided into small portions for examination, after preparation in the manner detailed above.

I.—Illustrations of Nerve Actions.

MATERIALS: *Needles.*

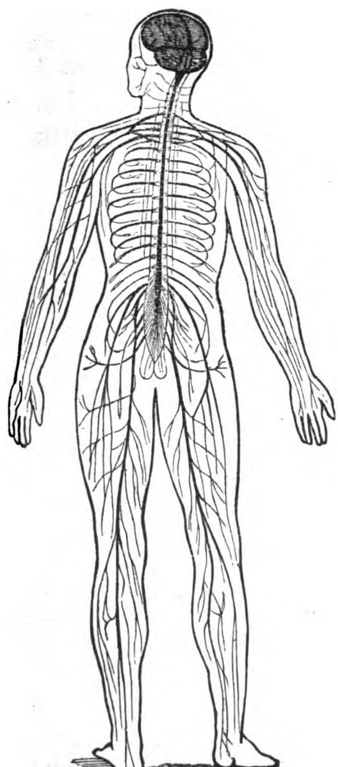

FIG. 20.

(*A*) *Voluntary.*

(1) Clasp the hands. Hold up one, two and three fingers successively.

(2) Write a sentence from dictation.

(3) Point the toes of one foot as in dancing.

(4) Nod the head in various directions.

(*B*) *Involuntary.*

(1) Notice the movements of the body in breathing, and to what extent they can be controlled by the will.

(2) Observe the result of touching a sensitive part of the person, such as a finger-tip or the lip, with the point of a needle. Compare the movements with those when the eyes are threatened with a blow; can either be entirely restrained? (*Fig.* 20.)

II.—Motor and Sensory Nerves.

MATERIALS: *Pencils; book; selection of articles in wood, china, or metal; pen; ink; ruler; pins; water; peas.*

APPARATUS: 3 *bowls; boiling flask; bunsen burner; retort stand.*

(*A*) Enumerate and illustrate practically, examples of the activity of motor nerves; *e.g.*, stamp the feet; follow movements with the eyes; trace figures in the air with the forefingers, etc.

(*B*) Record and illustrate examples of similar activity in sensory nerves—*e.g.*, strike the hand sharply with a pencil; touch different wet, dry, hot, cold surfaces; the surfaces of wood, metal, marble, or those of woollen or linen cloth, &c., and note the sensations received; hold a book at arm's length for three minutes, or until sensations of fatigue oblige the arm to be relaxed.

NOTE.—The connection between the sensory and motor nerves and their action have been illustrated by Professor Halliburton by means of the following simile. He compared the muscles of the body to the various divisions of an army; the sensory nerves to its officers, the central nervous system to the commander-in-chief; and the motor nerves to his aides-de-camp. Information is brought to the general by the officers, and orders despatched by him through his aides-de-camp to the divisions of the army, commanding them to perform certain movements.

(*C*) *To illustrate complex knowledge gained by, for example, cutaneous sensations.* Place an unfamiliar object in the palm of a companion whose hand is held behind his back. Ask him to enumerate the sensations of which he becomes conscious:—

(1) With the object in contact with the palm only.

(2) Assisted by the employment of the thumb and tips of the fingers.

NOTE.—The sensations will include those of weight, pressure, bulk, shape, temperature and texture.

(*D*) *The Localisation and Discrimination of Sensations.* Blindfold a member of the class; touch lightly some portion of his body with a pen dipped in ink. Ask him to indicate exactly the point touched, as soon as the pen is removed. (A blunt pin makes a good indicator). Measure with a ruler the distance between the ink dot and the point indicated. Repeat this experiment on various parts of the body, as the forehead, lip, back of neck, hand, heel, etc.

NOTE.—It will be evident that the delicacy of the sense of touch varies largely in different parts of the body. This is due (1) to the variations in the thickness of the epidermis and (2) to the number of sensory nerve endings in the different parts. The sense of touch is most delicate at the tips of the fingers, and on the face and tip of the tongue; it is least delicate on the back, or where the skin has become thickened by use and pressure, as on the forefinger or heel.

(*E*) *The Relative Nature of Sensations.*

(1) Prepare three bowls (*a*), (*b*), and (*c*).

Fill (*a*) with very hot water.
Fill (*b*) with tepid water.
Fill (*c*) with very cold water.

Immerse one hand rapidly in the following order, and compare the sensations of temperature experienced :—

In (*a*), then transfer rapidly to (*b*).
In (*c*), then transfer rapidly to (*b*).

(2) *The Use of Judgment with Sensation.* Perform Aristotle's experiment. Shut the eyes, cross the middle finger over the forefinger, and with the crossed ends rub along the ridge of the nose. Or hold a pea between the crossed fingers.

NOTE.—The first erroneous physical impression of the presence of two objects, which results from the unnatural position of the fingers, is rapidly corrected by the mental assurance that only one object is present. Reflection shows that as life advances and experience increases most sensations are corrected by the judgment.

III.—Examples of:—

(*A*) *Superficial Reflex Action.*

Materials: *Ruler.*

Observe the result upon the eyelids of an unexpected attempt to touch the eye-ball; or of passing a very bright light before the eyes.

(*B*) *Tendon Reflex Action.* Tap with a ruler the tendon just below the knee-cap of a person sitting upright, with one leg crossed over the other, the leg muscles lax, and the foot hanging free. Demonstrate by repeated tests that no exercise of will-power can alter the result. Confirm the fact by each pupil striking his own leg just below the knee-cap with his fingers.

Note.—Reflex actions have been defined as essentially purposive, but *involuntary*; they are chiefly associated with the performance of the vital functions, and with the protection of the body from injury. Some of them are *innate*, as, for example, breathing, or sucking; others are *instinctive*, *e.g.*, crawling, coughing, walking, or crying; or *acquired*, *e.g.*, swimming. They may be simple or co-ordinated, but whatever form they assume four things are necessary to their manifestation—(1) one or more perfect afferent or sensory nerve fibres; (2) a nervous centre in the spinal cord or brain for its reception and reflection; (3) one or more efferent or motor nerve fibres to conduct impulses to (4) muscular or other tissues. In (*A*) the reflex action is essentially protective in character. Compare choking to expel a crumb from the larynx.

Draw attention to the short time which elapses between striking the tendon and the result, a jerk, in (*B*). This time is occupied by the passage of the nerve current up the sensory nerves to the spinal cord and back through the motor nerves to the muscle in front of the thigh. The attention of the pupils should also be directed to the protective and "fitting" character of reflex movements, as shown by (*A*). Such reflex actions are always the same in form, whatever the kind of stimulus used; but the violence of the reaction increases with the strength of the stimulus. This fact can be easily demonstrated by varying the kind and strength of the stimulus used.

IV.—Inhibitory Nerves and their Functions.

MATERIALS: *Glass of Water.*

(*A*) Carefully count and record the pulse rate taken at the wrist of a person sitting at rest.

(*B*) Repeat the observation while a glass of water is (1) sipped, (2) rapidly drunk, keeping the finger on the pulse and noting any change in its rapidity.

NOTE.—Power to perform an action is counterbalanced by power to control its intensity. For example, the pneumo-gastric nerve sends branches to the heart, throat, lungs, stomach, and intestines, over all which parts it exercises *inhibitory* control, *i.e.*, it restrains and slows down their actions, which are stimulated into activity by branches from the sympathetic nervous system. If the controlling power of the pneumogastric nerve be increased, the heart's action will become slower; if it be diminished the beats will increase in rapidity. The changes which take place in the pulse rate during this experiment illustrate this inhibitory action of the pneumogastric nerve.

(1) The diminution which occurs is caused by the stimulation of the pneumo-gastric nerve by the act of drinking. As the action of this nerve is inhibitory, whereas that of the sympathetic nerve is accelerating, when the former is stimulated its controlling power is exercised with more force.

(2) Acceleration of the pulse rate succeeds the temporary diminution, because physiological inhibition is always followed by a rebound in the opposite direction. Hence this after-acceleration of the pulse. It is assumed that reference to the position and functions of the sympathetic nervous system will be made in the theoretical instruction associated with this practical work; of which functions the phenomenon of blushing affords an obvious illustration.

(*C*) *Partial Control of Reflex Actions by the power of Inhibition.* Hold the breath as long as possible; compare the distress experienced with the slight discomfort associated with stifling a yawn.

NOTE.—The duration of voluntary control (exercise of inhibition) over a reflex act is usually determined by its importance. It is short in the case of breathing or coughing, where its interference would imperil a vital function, but can be fully exercised in the case of yawning, for instance, where no ill effects follow inhibition (*i.e.*, repression) of the action.

V.—Tests to demonstrate what is implied by Nervous Reaction. *

MATERIALS: *Paper; pencils.*

Take the paper and pencils supplied. Start all tests at a given signal, and cease instantly at the word of command. Count and record on each occasion:—

(1) The number of crosses (+) made in 20 seconds.

(2) The number of horizontal lines (—) drawn in 20 seconds.

(3) The number of dots (:::::) tapped in 20 seconds.

NOTE.—These tests are designed to illustrate what is known as *rapidity of nervous re-action*, that is to say, (*a*) the length of time which elapses between the reception or application of a stimulus and the response in some form of activity to show that it has been felt; (*b*) the variation of this rapidity of response in individuals; and (*c*) the variation of this interval in the same individual at different times, when excitement, attention, fatigue, hunger or other causes affect the nervous system; also (*d*) the relation which exists between rapid re-action and skill—the rapidity in this connection being acquired by constant repetition of the same activity.

Before an average is taken, each test should be performed by all the students at least six times, but with intervening intervals, and, if possible, at different periods of the day. By this means comparisons of total and individual averages can be made, while the influence of fatigue on nervous tone and the increased speed acquired by practice can be noted, if the times at which the six tests are made are arranged somewhat as follows:—Test (1) 10 or 11 a.m. (2) 4 or 5 p.m. (3) 4 or 5 p.m. (4) 2 or 2-30 p.m. (5) noon. (6) 10 or 11 a.m. The average record made in this way by twenty-five teachers under almost precisely similar conditions was:—for crosses $11\frac{1}{2}\frac{1}{4}$ in 5 seconds; for the horizontal lines $20\frac{7}{8}$ in 7 seconds; for the tapping $41\frac{1}{6}$ in 5 seconds.

The interval between response and stimulus varies from one-tenth to one-fifth of a second; it is shortest for touch and longer for sight than for hearing.

* These tests cannot be satisfactorily performed by children.

VIII.—THE SYSTEMS OF THE BODY AND THEIR FUNCTIONS (*contd.*).

(A) THE NERVOUS SYSTEM (2).

The gross structure of the spinal cord; arrangement of grey and white matter. The gross structure of the brain; its convolutions; major divisions; identification of typical cranial nerves; the ventricles; arrangement of grey and white matter, etc.

I.—Observations on the Spinal Cord of an Ox.

MATERIALS: *Prepared spinal cord of an ox.*

APPARATUS: *Strong hand-lens; dissecting instruments; flat dish.*

(*A*) Take a portion of the prepared spinal cord of an ox. Careful observation with the naked eye will show:—

(1) The vascular membrane (*pia mater*) with which it is clothed.

(2) The arrangement of the grey and white matter of which it is composed, consisting of nerve cells and nerve fibres.

(3) The distinction between the anterior and posterior fissures, which almost divide the cord into two halves. Each of these fissures runs inward towards the bridge of grey matter; the anterior fissure is a distinct gap, and is lined with *pia mater* (the highly vascular membrane from the blood vessels of which capillaries branch off to the central parts of the cord); the posterior fissure, also of *pia mater*, forms only a septum, which serves as a partition between the two halves of the cord.

(4) Trace the two anterior and two posterior horns of grey matter, namely:—the grey crescents, lying on each side of the bridge, which are formed of the roots of the nerves of which the fibres pass out from the spinal column.

(5) Find, with a strong hand-lens, the central canal in the middle of the bridge of grey matter; it runs the whole length of the spinal cord.

II.—Spinal Nerves and their Roots.

MATERIALS: *Prepared spinal cord of an ox; coarse white and yellow wool; 6 empty cotton reels of different sizes; 1 metre green and 1 metre white flower-wire; plasticine.*

APPARATUS: *Dissecting instruments; hand-lens; flat dish.*

(*A*) Trace the fibres which pass out from the sides of the cord through the membrane.

(*B*) Cut the membranes away with great care; clipping the fibres of the inner side as close as possible to the membrane.

Look for the two roots of each nerve, and try to find the slight enlargements (*ganglia*) on the posterior root.

NOTE.—The general structure of the spinal nervous system may be demonstrated to young children by the following suggestive method. Take a long thread of coarse, white wool to represent the spinal cord. Thread on this an empty cotton reel; twist round the woollen thread and above the reel, 16 cms. lengths of green and white flower-wire, bringing out the green ends at the front and the white ends at the back; then unite these ends together in pairs, a green with a white, on each side of the reel to represent the motor and sensory nerves and their union into a nerve trunk. Thread a second reel on the wool, cementing it to the first by a $\frac{1}{8}$ inch layer of plasticine, to represent the disc of cartilage between the vertebrae. Again twist wires as before, and repeat with about eight or ten reels, which should, preferably, diminish in size, to correspond with the lumbar, dorsal and cervical vertebræ.

The relative position of the sympathetic nervous system may also be roughly represented by strands of yellow wool, passed down, one on each side of the column of cotton reels, and twisted lightly round each set of green and white wires where they are joined to illustrate the trunk of a spinal nerve. A knot made in the yellow wool between each such union would serve to represent the smaller ganglia, of which the sympathetic nervous system chiefly consists.

III.—Observations on a Sheep's Brain.

MATERIALS: *Sheep's brain, prepared as directed; a good diagram of the human brain; plasticine.*

APPARATUS: *Dissecting instruments; strong, sharp knife; hand-lens.*

(*A*) Take the sheep's brain provided, handling it throughout with great care. Observe the size and shape of the brain as a whole, and the relative position of the parts. Distinguish the surfaces as follows:—

(1) The dorsal surface, *i.e.*, the upper and more rounded portion.

(2) The ventral surface, *i.e.*, the lower and flatter surface.

(3) The posterior end which is less rounded than the anterior.

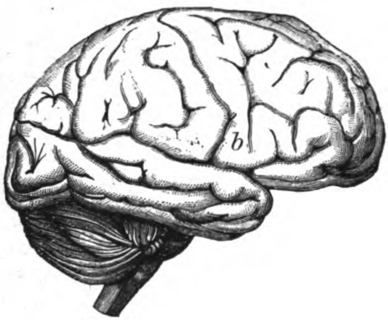

Fig. 21.

(*B*) Identify the three major divisions of the brain, which can be more easily distinguished by examining the lower, or ventral, side of the organ (*Fig.* 21):—

(1) The *cerebrum*, or larger brain, the seat of the intellect and centres of voluntary control, of which by far the larger part of the whole brain consists. This forms the prominent anterior portion, and extends backwards, almost concealing

(2) The *cerebellum*, or lesser brain, a much smaller division, posterior to, and somewhat beneath, the cerebrum. The function of the cerebellum is to regulate or co-ordinate muscular movements.

(3) The *medulla oblongata*, or spinal bulb, which lies beneath the cerebellum. In addition to its functions of transmitting sensory and motor impressions, the medulla oblongata is the seat of a number of centres for reflex actions of the highest importance to life, *e.g.*, the movements of the heart, of respiration, of swallowing, and of control of the blood vessels.

(*C*) Endeavour to distinguish one at least of the three membranes which support, protect, and nourish the brain :—

(1) The outer membrane (*dura mater*) will probably have been torn away with the skull.

(2) The delicate *Arachnoid membrane* is very difficult to detect, but can sometimes be separated from the surface by the aid of very fine forceps.

(3) The inner membrane (*pia mater*) is easily identified as it serves to hold in place the cerebral convolutions, and can be raised from their surface by forceps.

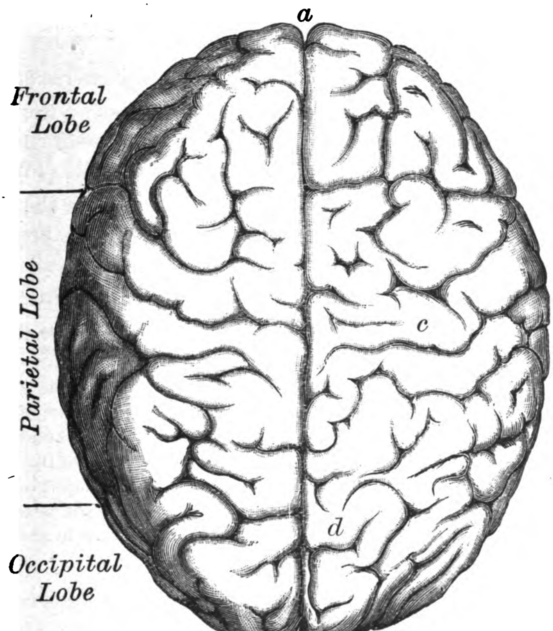

FIG. 22.

(*D*) Place the specimen on its ventral surface and examine the exterior of the cerebrum in greater detail (*Fig.* 22).

(1) The two hemispheres of which it is formed. Note the deep fissure by which the cerebral hemispheres are

divided; gently pull this median fissure apart and find the thick band, the *corpus callosum*, which joins the hemispheres on the ventral surface.

(2) Compare the folds, or convolutions, on the two sides, and detect any evidence of symmetrical arrangement either between the two hemispheres under examination, or in another specimen brain. Pass the handle of the scalpel (or a small paper-knife), down between the convolutions to show their depth.

(3) Find the following fissures, or deep depressions between the convolutions, which serve to map out the parts of the cerebrum into lobes:—

a The *median fissure* between the hemispheres (*Fig.* 22).

b The *fissure of Sylvius*. This begins about a third of the distance from the anterior to the posterior end of the brain, and runs upwards and backwards (*Fig.* 21).

c The *fissure of Rolando*, which starts from the median fissure in the anterior portion of the brain, and runs downward in front of *c* (*Fig.* 22).

d The *parieto-occipital fissure*, which begins at the median fissure, and runs across the brain, posterior to *d* (*Fig.* 22).

NOTE.—The grey matter of the brain, spread out over its surface, is composed of nerve cells having the highest functions of any of those found in the nervous system. It is known as the cerebral cortex, and the amount varies directly with the extent of convolution of the surface. The object of the convolutions is, indeed, to increase the brain area, which probably amounts in a well developed brain to about 33 sq. metres, or 300 sq. ft.

(*E*) Proceed to localise the lobes defined by these fissures:—

(1) The *frontal lobe*, in the anterior part of each hemisphere.

(2) The *occipital lobe*, in the posterior part of each hemisphere.

(3) The *parietal lobe*, along the median line between (1) and (2).

(4) The *temporal lobe*, below the fissure of Rolando on each side.

NOTE.—Interest in the foregoing observations will be much quickened if they be accompanied by an elementary introduction to the work accomplished in the localisation of brain functions by Schäfer, Ferrier, Sherrington, Horsley and other specialists in brain anatomy and physiology. At the same time attention must be drawn to the tentative nature of many of their conclusions, in consequence of the extreme complexity of brain structure and function, the nervous tissue being composed of millions of nerve cells and of the association fibres, by which groups of cells are brought into communication one with the other. To illustrate this complexity it may be stated that in a certain sense stimulation of *any* part of the cortex of the brain gives rise to muscular sensations and reactions, that is, to outgoing impulses, though a large part of the same surface is evidently also composed of incoming fibres, bringing afferent sensations. The result of this close association of sensory and motor elements is seen in the case of the regions devoted to the special senses, such as sight, hearing, and smell, for the motor reactions which arise from the stimulation of these areas take place in the muscles which control the eye, ear, and nose. The experimental determinations of brain areas in man are, of course, few in number, and most descriptions refer to the brains of monkeys, which in a general way are probably more or less similar to those in man, though with wide variations (*Fig.* 23, *p.* 106).

It is firmly established that the cortex of the anterior convolutions of the cerebrum contains numerous centres for delicate muscular and motor adjustments, connected by countless fibres of association, which connections are formed as the result of repeated responses to stimuli. Speaking generally, therefore, the motor areas which control the muscular movements of the body are situated *anterior* to the fissures of Sylvius. Roughly speaking, they form the frontal and parietal lobes and occupy the convolutions around the fissure of Rolando, turning over the edge of the hemisphere into the marginal convolution of the mesial surface. Those areas concerned with the sensations of the special sense organs of sight, hearing, and smell are *posterior* to the fissure of Sylvius; that is, they lie in the temporal and occipital lobes.

The superior median and ascending convolutions are concerned respectively with the movements of the hip and knee, of the head, shoulder, elbow, wrist, fingers, eyelids,

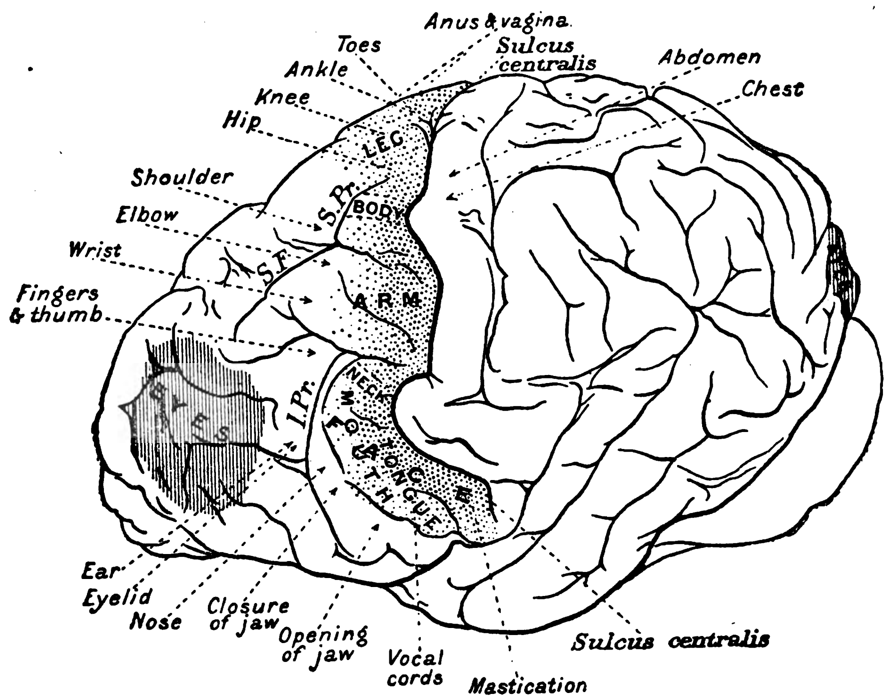

FIG. 28.

Brain of Chimpanzee, from "Handbook of Physiology," by Professor Halliburton, M.D., F.R.S., by kind permission of Mr. John Murray, Albemarle St., W.

mouth, tongue, mastication, swallowing, and speech, while the centre for eye movements is situated in the inferior frontal convolution. Authorities state that the representations of different muscle groups in the cortex of the cerebrum is not dependent on their mass, but is related rather to the refinement and complexity of the movements which these muscles effect; much larger areas, therefore, are devoted to the face and arm than to the big muscles of the trunk and leg, while in the former greater extension is given to the thumb and forefinger, or to the tongue and muscles of speech, than to movements of the whole limb. Relatively few of these higher centres are active during the first days after birth, but are called into activity by external stimuli, connection between them being gradually and permanently established by the formation of fibres of association, under the combined effects of nutrition, stimuli, and function. Where one or other of the former are absent or deficient function is delayed, imperfect, or arrested. Hence the necessity for care during the early years of life when the power of rapid and progressive brain growth is at its best.

The sensory areas of the human brain are mapped out with less certainty than are the motor areas, with which they are in part coincident. Each year, however, shows fuller and more accurate conclusions formed on the whole subject, following upon constant investigations by the comparative method. The results of such investigations are of quite as much value to those concerned with the care of young people as to the medical profession. In the one case realisation that the parts of the brain evolve in a definite order and at different age periods enables parents and teachers to adjust the environment of the growing child to its physiological needs, and thus to develop its fullest capacity; while though, at the same time, the surgeon receives assistance in his efforts to determine the cause of diseases such as epilepsy, insanity, and paralysis, which enables him in many cases to restore health and power for work which would be impossible without this knowledge, his skill is concentrated upon remedial treatment, rather than upon those developmental and preventive measures which together represent the function of education, whether at home or at school.

(*F*) Turn the brain on to its dorsal surface and make out as many as possible of the following details of its structure. Success will depend to a large extent upon the condition of the

specimen and the degree to which its normal shape has been preserved in the course of the preliminary preparations.

(1) Notice the symmetrical position and conformation of the two hemispheres which together form the cerebrum.

(2) Look for the cut end of the spinal cord and trace the bulbous outline of the *medulla oblongata* into which the cord widens at its upper end. For this purpose raise the cerebellum and push it gently forwards. In order to make this observation satisfactorily, it may be necessary to remove the thin membranous covering from the dorsal side of the medulla.

The tissues given off from each side of the cord and the medulla, by which they are connected to the cerebrum, are composed of numberless nerve fibres and form some of the cranial nerves. Of these the tenth pair, the *pneumo-gastric* nerves, are of great importance, they supply the larynx, the lungs, the liver, the stomach and the heart.

Other pairs of nerves are connected with the jaws, facial muscles, tongue, etc.; while still other of these fibres will be identified in (3) as the *crura cerebri.*

(3) Notice the large mass of transverse fibres extending across the brain just above the bulb, which it practically encircles. This forms the *pons varolii*, a sort of bridge uniting one half of the cerebellum to the other. The nerve cells in its substance are connected with the roots of some of the cranial nerves.

Raise this bridge gently with the handle of the scalpel and observe the longitudinal character of the mass of nerve fibres beneath. If necessary slice off a superficial layer, when the formation will be easily perceived.

These fibres are both motor and sensory and are given off from the bulb. They pass among and between the transverse fibres of the pons varolii and then come to the surface again in the form of two broad, diverging bundles or ropes, the *crura cerebri*, easily seen on the ventral surface of the brain, on the anterior side of the pons.

Follow their course until they disappear, one into each of the cerebral hemispheres.

(*G*) (1) Examine the exterior of the cerebellum as to shape and size. Observe how completely it overlaps and shelters the dorsal surface of the medulla oblongata.

(2) Notice the absence of convolutions in this part of the brain and the series of characteristic transverse folds which take their place.

(3) If the specimen be in good condition, trace out the division of the cerebellum into right and left hemispheres by a deep median cleft.

The cerebellum is firmly connected to the rest of the brain by the transverse fibres which help to form the pons varolii, these constitute what is known as the *middle peduncle* of each half of the cerebellum. Other bands of fibres which connect the medulla oblongata and the cerebellum to the cerebrum are known respectively as the *superior* and *inferior* peduncles.

(*H*) (1) With the brain on its ventral surface raise the posterior end of the cerebrum, try to find two lumps on the dorsal surface of the crura cerebri just before they pass into the substance of the cerebrum. These are two of the four *corpora quadrigemina*, twin-like bodies much larger in the lower animals than in man. They are centres for sensation, especially connected with the vision and with the movements of the pupils of the eyes.

(2) Turn the brain over and find the cut ends of the round, relatively firm, optic nerves on its ventral surface. Trace the nerves of the two eyes to where they meet and are connected together at the *commissure* or *chiasma* which is somewhat quadrilateral in form.

Numerous fibres of these optic nerves from the two eyes cross within the central part of the commissure, and pass from the hemisphere of one side of the cerebrum to the optic tract of the other.

(3) Follow one of the optic tracts, that is the posterior or lower portions of the quadrilateral commissure, and see how they form flattened bands on the ventral surface of the crura cerebri to whose anterior margins they are closely attached.

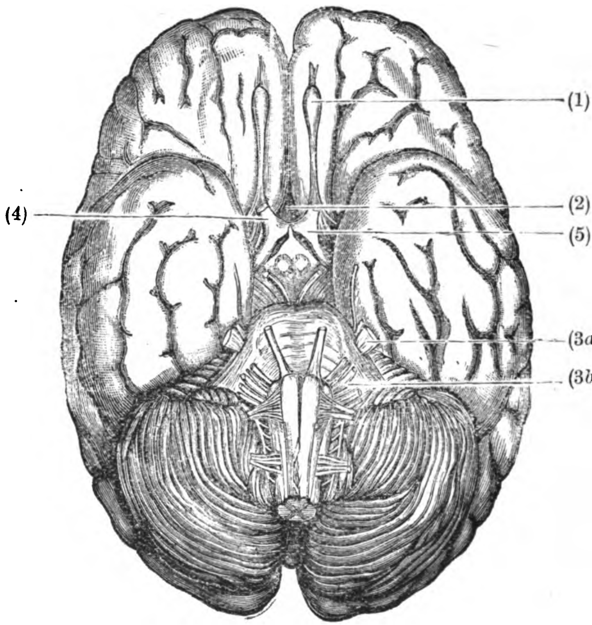

FIG. 24.

(4) Separate the *pia mater* (the delicate transparent membrane which closely invests all parts of the brain) where necessary in order to raise the cerebrum more completely, the remaining two corpora quadrigemina will then become visible.

(*J*) Find the following parts on the ventral surface of the whole brain (*Fig.* 24):—

(1) The prominent *olfactory bulbs*, many times larger in relative proportion in the sheep than in man.

(2) The *pituitary body*, a small, reddish-grey mass just above the optic nerves, which appears to exercise some

controlling influence over the osseous system of the body, for hypertrophy, or overgrowth, occurs if the pituitary body be diseased.

(3) Trace, with the assistance of a good print of the human brain, as many as possible of the *cranial nerves*, especially (*a*) the *trigeminal nerves* as they arise from the sides of the pons, and (*b*) the *pneumo-gastric nerves* as they pass out of the medulla oblongata.

(4) The cut ends of the *optic nerves*.

(5) The *optic chiasma*.

(*K*) *Examine the interior of the brain.*

(1) Remove a vertical layer from the upper part of one hemisphere of the cerebrum with a long, sharp knife. Observe the two colours of the tissue (a dull brown and a pale yellow, which in life are respectively a greyish-pink and white) (*Fig.* 25). Compare their arrangement with that in the spinal cord.

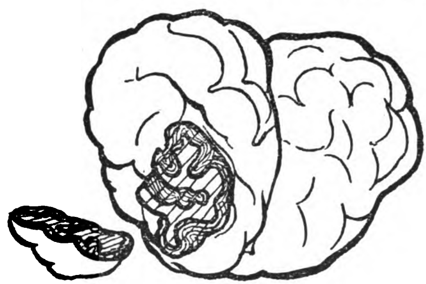

FIG. 25.

(2) Cut a second section a little deeper, about on a level with the top of the band of tissue (the *corpus callosum*), which connects the two hemispheres. It will be seen that this band does not extend fully to either the anterior or posterior of the cerebrum.

(3) Make another vertical section of the hemisphere, about 5 cms. ($1\frac{3}{4}$-in.) thick, in order to observe the complicated structures thus exposed. The cavity in the middle is the lateral ventricle. The third ventricle is dorsal to the optic tracts. It communicates by a narrow Y-shaped passage, the *foramen of Munro*, with the lateral ventricles. Each of the five ventricles is a cavity of a very peculiar

shape and they correspond respectively to the five lobes into which the exterior of the cerebrum is conventionally divided. They are lined with very delicate membrane, and moistened by a serous fluid.

(4) Make a series of horizontal sections, each a few cms. thick, through the untouched cerebral hemisphere.

At the second section a prominent almond-shaped body will come into view, it lies rather obliquely upon the surface of the crus cerebri just where its longitudinal fibres pass into the base of the hemisphere. This is one of the *optic thalami*, so called because the older anatomists supposed these centres to be connected with vision, whereas they are sensory centres receiving sensations, probably those of touch, and transmitting them upwards to the centres of consciousness. The optic thalami form projections on the outer side walls of the third ventricles in each hemisphere, also on the floor of the large lateral ventricles.

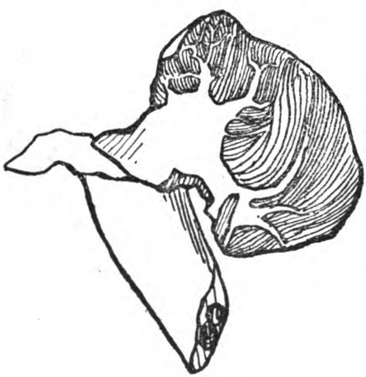

FIG. 26.

(5) Remove the cerebellum by cutting through the peduncles. Divide one-half transversely, and carefully observe the peculiarities of structure, absence of convolutions, and arrangement of grey and white matter; notice the tree-like arrangement of the white matter, from which has arisen the name *arbor vitæ*, or tree of life (*Fig*. 26).

(6) Make a transverse section through the *medulla oblongata* and observe the arrangement of the grey matter. Make a similar section through the *pons varolii*, and notice the arrangement of the fibres; does this resemble that in the cerebrum, cerebellum, or in the spinal cord?

NOTE.—The *corpora quadrigemina* have been selected for more detailed study in order to introduce the student to some conception of the localisation of function in the brain, of its intricacies, and the means by which sense impressions are received, transmitted, and recorded. (*See* (*H*) (1), page 109).

The *corpora quadrigemina* also receive impulses, which are the result of the stimulus of the visual end organ, these may be transmitted upwards to the cerebrum and result in a sensation of light, or they may serve as a centre for the distribution of impulses, resulting in co-ordinated movements, without previous peripheral disturbance sufficient to affect consciousness. Somnambulism affords an illustration to the point.

The cerebral hemispheres are believed to possess the highest nerve centres associated with *intelligence*, *thinking*, *willing*, *feeling*, and *consciousness* generally. Under these, however, is a series of subordinate or lower centres; first of all those of the ganglia at the base of the brain, next, those of the cerebellum, then those of the medulla, and lastly, those of the spinal cord. Of the basal ganglia the *corpora striata* possess centres for the control of voluntary motion, the *optic thalami* are centres where sensory impressions may be generated, and the *corpora quadrigemina* are specially connected with visual sensations.

The centres in the *cerebellum* are for regulating muscular movements; and in the *medulla* are situated the chief centres that maintain the movements of the vital organs.

To take an illustration of these various functions. Say that a boy, walking along the street, sees an obstacle in his path. The rays from this obstacle stimulate the end organs in the eye, and the nerve impulses so generated, pass to the *corpora quadrigemina* and are distributed to the higher centres in the cerebrum, when the boy becomes conscious of seeing. He decides to walk round the obstacle, and, thereupon, impulses are transmitted down to the *corpora striata*, and so to the spinal cord, and down to the muscles of the leg, causing the proper movements to effect the end aimed at. But if a man is walking through a street with a preoccupied mind, he may notice nothing in his path, nevertheless he avoids obstructions in his way. Here also the nerve endings in the retina are excited and impulses reach the *corpora quadrigemina*, but instead of being distributed along the paths to the higher centres, they are switched off, or deflected to the *corpora striata*, which act as centres for controlling reflex movements, and from them the nerve

impulses pass down the spinal cord, which produce the required movement of muscles. This last is an example of a very complex reflex action.

The shorter path taken by the nervous disturbance in the second case is due to the fact that the paths between the higher brain centres were already occupied by the passage of nerve-impulses generated by other stimuli; a very powerful stimulus of the retina would have therefore been necessary to set going impulses powerful enough to overcome those in occupation.

Considerable assistance is rendered to those who have a very elementary knowledge of the complicated structure of the brain if a rough model of the parts be made, as suggested by Prof. Leonard Hill in his "Manual of Physiology" (Arnold). He directs

(1) That a lump of putty, or preferably of plasticine, be rolled into a cord about as thick as the little finger and about 20 inches long to represent the spinal cord, one end being thickened for a length of two inches to form the bulb.

(2) Lay the whole on a board, and divide about half-an-inch at the upper end of the bulb into two short cords to represent the peduncles of the cerebral hemispheres.

(3) Make four little round lumps of the plastic material and fix them to the back of the cord just below this division, two close together on each side (they are the corpora quadrigemina), and just below them again, fix a large lump to represent the cerebellum.

(4) Then take a band of plasticine to represent the *pons varolii* and pass it across and underneath the rope from one side of the cerebellum to the other. (It is formed by the two middle peduncles of the cerebellum.)

(5) Make four little ropes; fix two to the upper surface of the cerebellum to represent its superior peduncles and two to its lower surface, which latter must pass, one on each side, to join the *medulla oblongata;* they are the inferior peduncles of the cerebellum. Make a fissure in the median line of the cerebellum to divide it into hemispheres.

(6) Add small lumps to the two peduncles of the cerebral hemispheres to represent the *basal ganglia* (which include the corpora striata, concerned with the control of voluntary motion, and the *optic thalami*, centres where sensory impressions may be generated); crown each with a very large lump to represent the cerebrum and join the hemispheres (which should be marked with convolutions), with a thin band, the *corpus callosum.*

VIII.—THE SYSTEMS OF THE BODY AND THEIR FUNCTIONS (*contd.*).

(B) THE CIRCULATORY SYSTEM.

Presence of blood in the body. Characteristics of the blood vessels from external observation. Characteristics of blood. Effects of respiration and of carbon monoxide gas on blood. Dissection of a sheep's heart.

I.—The Presence of Blood in the Body.

MATERIALS: *Needle; string; scissors.*

(*A*) Run a sharp, clean needle horizontally through the upper layer of thick skin on the outer surface of the forefinger. Does blood flow, or does compression round the spot cause any blood to exude?

(*B*) Tie a string tightly round the last joint of the first finger of the left hand until it becomes a deep red colour. Further increase the congestion by bending the tip of the finger so far as the tight band permits, then prick the finger sharply with the needle just at the base of the nail; there will be little pain, but a large drop of blood will exude from the spot.

(*C*) Trim a shaving off a finger nail.

(*D*) Snip the end of a hair on the head. Compare the results in each case.

NOTE.—That nearly every part of the body bleeds when cut is a generally familiar fact, but these observations will demonstrate that blood is not present in some of the most exposed parts (as the epidermis and its appendages of hair and nails). The needle must be scrupulously clean. Pupils should therefore be systematically trained to sterilise any instrument used for this or other experimental purposes before touching any part of the body. This can be accomplished (1) by placing the needle or other instrument in boiling water for 20 minutes, or (2) by exposure to a high temperature in the air-oven; or (3) as effectually and more simply by passing the point of the instrument rapidly to and fro through the hottest part of the flame of a Bunsen burner.

II.—Tests for External Indications of the Presence of Blood in the Body.

(*A*) Stand up, with one arm hanging freely at the side. Hold the other arm straight up above the head, as high as the clothing will allow, for about a minute. Notice :—

(1) The difference in the colour of the two hands.

(2) The differences in

(*a*) The sensation of fulness ;

(*b*) The appearance of the two arms ;

(*c*) The temperature, tested roughly, by placing the backs of the hands against the cheek or lips.

(*B*) Lightly close one hand for half-a-minute, and observe the appearance of the finger nails ; then straighten the fingers back as far as possible. The change of colour indicates a diminished blood supply. Confirm this observation by noticing the change of colour when a finger nail is pressed (1) on its surface, (2) on its free end, and (3) on its sides.

(*C*) Press with the finger tips of one hand on the back of the other, and again observe the changes which result.

(*D*) Tie a piece of tape tightly round the finger. Compare the resulting changes in colour, size, sensation and temperature with (*A*), (*a*) and (*b*).

III.—**The Characteristics of the Blood Vessels from External Observation.**

(*A*) Bare one arm, swing it round in a circle once or twice and then let it hang down for a minute. Certain blood vessels will become prominent. Stroke these gently downwards towards the wrist. Then, without raising the arm, reverse the movement and stroke towards the elbow. Notice whether little knots or swellings rise in each case. When observed these draw attention to the fact that the backward progress of blood in the veins is opposed by *valves.*

(*B*) (1) Bare the left arm, squeeze and compress it from the wrist towards the shoulder with the right hand, and

immediately bind a bandage very tightly above the elbow, making a note of the appearance of the limb and the sensations felt in it. Compare these with the sensations which follow upon loosening the bandage.

(2) Repeat the process, but bind the arm lightly only.

NOTE.—The pupil will probably be already aware that valves are pouch-like folds of the inner walls of veins, especially in those veins situated in the more muscular parts of the body. The little knots are really dilatations of the walls of the vein, caused by the pressure of the blood above a valve which bars its backward movement.

In (*B*) (1) the preliminary squeezing of the muscles from wrist to shoulder will drive out a proportion of the venous blood from the limb; in consequence, when the arteries as well as the veins are compressed by a tight bandage, no blood can enter the part, and it therefore becomes pale and numb.

In (*B*) (2) the veins only will be compressed, with the result that the arm will become swollen and blue. The experiment illustrates the existence of two classes of blood vessels, *arteries* and *veins*, of which the former lie deeper than the latter, and are less easily controlled.

It will be evident that the temperature, size, sensations and colour of the arms, hands and nails are dependent upon the blood supply they receive—an inference which may be applied to all parts of the body, confirmed as it is by other and more elaborate experiments.

It was indeed upon observations of this character that William Harvey (1578-1657) first based his opinion that the blood circulated in the body; that is, that it moved in a circle, and not merely to and fro in haphazard fashion, as had been hitherto believed. Structural and experimental facts confirmed his opinion by undeniable proofs; and since his time, many more proofs have been accumulated, so that eleven at least are quoted in support of his discovery. These include:—

"The existence of two distinct sets of tubes in connection with the heart, namely, the arteries and the veins."

"The existence in one of these, the veins, of valves which will only allow the passage of the blood in one direction."

"The fact that the blood spurts with great force and in a jerky manner from an artery opened during life, each jerk corresponding with a beat of the heart."

"That if the large veins near the heart are tied, the heart becomes pale, flaccid, and bloodless, and on removal of the ligature the blood again flows into the heart."

"If the aorta is tied, the heart becomes distended with blood, and cannot empty itself until the ligature is removed."

"Harvey also drew attention to the fact that there is general constitutional disturbance resulting from the introduction of a poison at a single point, and that this can only be explained by a movement of the circulating fluid all over the body."

The changes observed during the foregoing experiments are caused:—

(1) As regards the colour of the part concerned, by stagnation of the blood, or by its temporary exclusion from the part to which pressure is applied. When great or severe pressure interrupts the circulation, the blood assumes a purplish hue, as a result of the rapid accumulation of venous impurities; when, however, the pressure is momentary, the blood is temporarily squeezed out of the capillary vessels, so that the skin becomes almost colourless, but immediately regains its normal tint as unimpeded circulation is re-established.

(2) The increase of size in the ligatured joint or in the pendent hand in II. (*A*) and III. (*B*) are also caused by interference with free circulation. The deeply-set arteries continue to carry a supply of blood to the parts which cannot be removed by the more superficially situated veins, in consequence of the compression to which they are subjected; while in II. (*A*) the force of gravity renders the return of the venous blood more difficult, especially when a limb is long pendent, than when its position is reversed. Increased blood supply to a part implies increased heat, the blood being the chief source of heat to the tissues. Finally, where compression interferes with the circulation, numbness or loss of sensation follows, because nerves can only register sensation when nourished and stimulated by a supply of wholesome blood. Compare the result of compressing the femoral artery by sitting on a hard seat for a considerable time, "pins and needles" or "the foot or leg going to sleep;" the inability of these numbed members subsequently to support the body or to feel are all evidences of numbed nerves, starved by deficient blood supply in consequence of pressure upon the blood vessels.

(*C*) (1) Place the forefinger lightly upon any one of the surface veins; note the absence of any pulsation.

(2) Find the pulse in (*a*) the wrist, in (*b*) the temple, (*c*) near the windpipe, by placing the second and third fingers of one hand (*a*) on the radial artery in the wrist, *i.e.*, on the under surface of the wrist, just below the thumb; (*b*) on the temporal artery, which can be felt on the temporal bone in a line with the outer angle of each eye; (*c*) the external carotid artery, which lies beneath the angle of the jaw. Observe the deeper position of the vessels in which pulsation can be felt.

(3) Place the hand lightly over the heart and compare the two sensations, *viz.*, the beat of the pulse in the wrist or temple, and that of the heart.

(*D*) (1) Count the pulse for 30 seconds in any one of the above localities while sitting at ease.

(2) Rise quickly and count again.

(3) Jump or run rapidly for a few moments and again count the pulse. Observe how the rapidity is affected by posture and exercise.

NOTE.—It will be best to discard the first attempts to count the pulse, as the results will be unreliable, owing to inexperience, excitement, or other causes. To obviate the risk of any directly personal observations or applications, record each pupil's results on the blackboard, and base all conclusions upon the average of the class.

IV.—The Characteristics of Blood.

MATERIALS: *Needles; string; sheet of white paper; red and white plasticine; blood clot from butcher; filter paper; dilute hydrochloric acid; ammonia;* 15 *cms. thin rubber tubing; scarlet thread; tissue paper; strips of waterproof paper, stout linen and calico; thread; currants or cranberries.*

APPARATUS: 2 *glass slides; cover glass; tumbler; bottle; pipette; china bowl; retort stand; bunsen burner; sand bath.*

(*A*) (1) Tie a string round the last joint of one finger and prick the skin with a clean needle near the root of the nail,

as directed in I. (*A*), *page* 115. Spread out the drop of blood which exudes on a slip of clean glass; hold the glass over a sheet of white paper and note the *yellow* appearance of the drop.

(2) Place another large drop of blood, obtained in the same way, on a second piece of glass. Cover it at once for five minutes with a small glass tumbler, previously moistened inside with water or with the breath. Remove the tumbler, and note the firm jelly, or clot, into which the drop of blood has set.

(3) Again moisten the cover glass and replace it for half-an-hour. Notice the further changes which will have taken place; there will be a tiny red clot floating in a nearly colourless fluid (*serum*).

(4) Obtain a drop of blood as directed in (1) and allow it to fall on a slip of glazed, neutral litmus paper. Wash the blood away after ten or fifteen minutes and observe the evidence that blood is an alkaline fluid.

NOTE.—A blue stain will be left where the blood fell on the litmus paper. The alkalinity of which this is a sign is due to the presence of *sodium* (both carbonate and phosphate) in the blood.

(*B*) Compare these observations in (*A*) (2) (3) with the changes which occur in fresh blood supplied by a butcher. Notice:—

(1) The colour, shape, size, consistency and position of the jelly-like *clot* after one, two, three and six hours; and daily for a week.

(2) The position, colour, consistency and quantity of the straw-coloured *serum*, as this forms in the vessel. How soon do the first drops appear?

(3) Place the jar containing the blood under a fine jet of water from a water-tap, and allow the water to run into it gently for some hours. Then notice the amount, form, consistency and colour of the *fibrin* which remains in the jar.

NOTE.—Arrangements should be made to fetch the blood required for this experiment from the butcher's about an hour after he has collected it fresh into a china pot, or preferably, into a wide-mouthed glass fruit-jar. He should be asked to set the

vessel aside in a cool place, where the contents will not be shaken or otherwise disturbed until called for.

The *bright red* colour will change to a *deep claret* during this period, and the fluid, which becomes viscid very soon after being shed from the body, will have assumed a jelly-like consistency, so that it could be turned without difficulty into another vessel if necessary; though it is better left undisturbed. The clot should be kept under observation for some hours; preferably, if weather or storage arrangements permit, for at least a week. The clot will gradually shrink in size until finally its dimensions are reduced by about one half. If left undisturbed for some days the serum will be squeezed out of the mass by the gradual contraction of the fibrin fibres, the formation of which fibres is coincident with the shedding of blood and is also the cause of coagulation.

These fibres at first extend from one side of the vessel to the other, forming a close network in which the *corpuscles* are entangled. The first effect of their formation is the jelly-like consistency assumed with greater or less rapidity, according to the quantity of blood concerned; the second is the separation of the solid mass of corpuscles from the liquid serum. This results from the shrinkage of the fibrin fibres, which shorten, lose their hold upon the sides of the vessel and form a cylindrical clot. The difference between the apparently similar fluids, the *plasma*, in which the blood corpuscles float in the blood vessels, and the *serum*, which surrounds a blood clot, lies in the absence from the latter of the liquid proteid substance *fibrinogen*, which changes into solid fibrin when blood is shed, and provides the natural means of preventing loss of blood by closing up injured blood vessels, a phenomenon known as coagulation.

To prove the presence of fibrin in fresh blood, the butcher must be supplied with a few twigs and a second vessel, and must be requested to stir the blood collected therein for several minutes immediately it is shed, preserving the twigs he uses for inspection when the vessels are collected. The stringy mass on the twigs must be washed under a tap, after which the white, elastic fibres can be tested for the presence of proteid by either of the tests given in IX. "*General Constituents of the Body*," I. (*D*), *page* 168. The red liquid which has been thus defibrinated will exactly resemble blood so far as ocular observation is concerned, but however long it be allowed to stand no clot will form, thus proving that the coagulating element has been removed.

Serum is the great purveyor of nutriment to the tissues; the red corpuscles are oxygen carriers, and in the white corpuscles is found one of the chief sources of self-protection possessed by the body. This is a consequence of their power to seize upon and devour micro-organisms or their products when these gain access to the tissues, through which the white corpuscles circulate in the capillary vessels. When such foreign bodies or their *toxins* (poisonous products) menace the health and well-being of the whole body or of any of its parts, the white corpuscles assemble in large numbers, and in most cases are sufficient to destroy the invaders, or largely to neutralize the results of their presence.

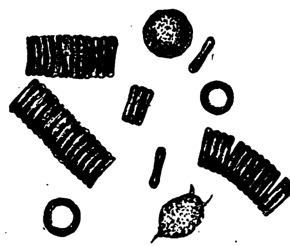

FIG. 27.

The appearance and characteristics of the blood corpuscles will be more intelligently realised by the pupils if highly-magnified specimens are exhibited with the aid of a good microscope. If possible, the demonstrator should place a drop of his own blood or that of a pupil, upon a clean, slightly-warm glass slide, cover it with a cover-slip and submit it for immediate examination. As both the high and low powers should be used the number of observers must be limited on each occasion, if all the desired points are to be perceived. These should include the following:—

(1) That the red corpuscles only appear red when massed together; singly they look pale and yellowish. To impress their infinite number it is well to state that about five millions are present in a minute drop of healthy blood as their actual dimensions are hard to realise, *viz.*, $\frac{1}{3200}$ inch in diameter and $\frac{1}{12000}$ inch in thickness.

(2) That red corpuscles are circular, bi-concave, and tend to congregate into rows, like rows of coin, technically described as *rouleaux* (*Fig.* 27). It will take some time and trouble for an inexperienced eye to distinguish the red

corpuscles which are on edge (a position which permits their bi-concavity to be seen) from those which present a surface view.

(3) Effort must be made to detect specimens of the relatively few white blood corpuscles, present in the proportion of one to five or six hundred red corpuscles. They look more or less round and white, though their shape varies according to the course they are pursuing, being capable of variation in ways exactly comparable to those of the amœbæ. References should be made to the great benefit to the body which results from this power of movement, by which the white corpuscles can, when necessary, force their way through the walls of the blood vessels into the substance of the tissues, and exercise their protective influence at any point in the body where poison has penetrated or injury has been inflicted.

(4) The fact that the blood corpuscles float in the colourless serum becomes evident if slight pressure be made on the cover slip.

(*C*) Find out, so far as possible, the composition of blood serum, as follows:—

(1) Transfer some of the clear serum collected in (*B*) (2) into a large test tube by means of a pipette. Place about 10 c.c. of this serum in a test tube and heat very gradually over a Bunsen burner. What food stuff in ordinary use does the serum recall when it becomes cloudy and coagulated by the heat? (*cf.* IX. "General Constituents of the Body," I. (*B*) (1), *page* 167).

(2) Drop a similar quantity of serum into a second test tube and add two or three drops of dilute iodine solution. Compare the result with that obtained in "Phenomena of Life," I. (*C*), *page* 17. Is starch present in the serum?

(3) Allow a drop of serum to fall upon a piece of tissue paper, and set it aside for a few minutes. Compare the greasy stain still visible on the paper (after time has been allowed for any moisture to evaporate), with that left after a drop of oil or cream has been allowed to fall on a piece of similar paper. Does this comparison assist you to determine whether fat be present in serum?

(4) Place 20 c.c. of serum in a porcelain basin and evaporate it slowly to dryness on a sand-bath; cover the basin, and heat the residue until it is burned. Cool, and add a few drops of dilute nitric acid. The slight effervescence or escape of bubbles of gas which follows shows that salts (carbonates) are present. When an acid is added to a carbonate in the presence of water, carbon dioxide is formed, producing effervescence such as takes place in this instance. Prove this fact by placing a very small pinch of carbonate of soda in a porcelain basin and adding a few drops of dilute nitric or hydrochloric acid.

NOTE.—To give young children some idea of the appearance, shape, and relative proportions of blood corpuscles, roll some red plasticine or modelling clay into the size of a marble, pressing it between the thumb and forefinger, so as to make the centre concave and to keep the edges round. Make at least two dozen such balls. These would represent the bi-concave red corpuscles. Use white plasticine or clay for the white corpuscles; these must be larger in bulk and fewer in number than the red ones, and they should also be irregular in shape, so that their amœboid properties may be explained.

To illustrate that blood receives its characteristic colour from the red blood corpuscles, fill a bottle with red currants or cranberries, and add water. The fluid may be compared to the colourless serum, and the berries to the red corpuscles, which, seen in mass, tint the whole mixture.

To represent the structure of an artery, wind some red thread closely round a piece of thin rubber tubing, covering the whole with a layer of tissue paper. The red thread exemplifies the non-striated, smooth muscle fibres, which are arranged circularly in the walls of arteries; these, when they contract, reduce the size of the tubes and thus diminish the flow of blood, which again increases as they relax. The tissue paper corresponds to the connective tissue (outer) coat, and the rubber tube to the epithelial (inner) coat of such arteries; while the muscular coat constitutes the median layer.

The shape and function of the venous valves may be illustrated as follows:—Take a strip of stout, stiff linen or waterproof paper (A) (*Fig.* 28), 30 cms. ($10\frac{1}{2}$ in.) long × 10 cms. ($3\frac{3}{4}$ in.) broad, and three strips of calico (B), 12 cms. ($4\frac{1}{2}$ in.)

long × 4 cms. (1½ in.) broad. Lay (A) flat on the table; fold it first in half and then in quarters, creasing the dividing lines sharply; four sections will result. With a pair of compasses draw two half-circles on each strip of (B), which should join in the middle; two half-moon shaped pockets will then be outlined on each strip, resembling in shape those formerly used for watch pockets. Lay the strips of calico (B) across the three creased lines on (A), and fix the corner of each strip to (A) by means of small pins, at a distance of 1 cm. from the edges. Attach the middle of each strip in similar fashion to the middle of (A) so that the three strips sit full on the foundation. Stitch firmly round the pencil lines on (B) so that six pockets are attached to (A), two in each of the three strips. Join (A) into a cylinder by stitching down the centimetre of material left free on each side of the pockets, then pour water through it, first from one end, then from the other. In the one case the pockets will distend with water so that no more can travel along the cylinder; in the other, however, when the position is reversed, they will lie close to the walls of the tube and offer no obstruction to the free passage of the fluid. This will serve to show the action of venous valves at work and at rest.

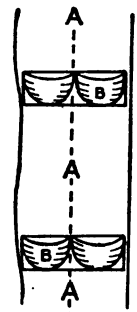

FIG. 28.

V.—The Effects of Respiration on Blood.

MATERIALS: *Fresh blood; jar of oxygen gas.*

APPARATUS: 3 *small flasks; rubber cork with hole; glass tube; gas-jar; taper.*

(*A*) Take three small flasks, (*a*), (*b*), (*c*), and place some fresh blood in each. Insert in (*a*) a rubber cork through which passes a glass tube. Blow through the tube, observing any change which occurs in the appearance of the blood.

(*B*) Make a small quantity of carbon dioxide gas in a gas-jar by inverting the jar over a lighted taper. Remove the taper when extinguished, and holding the jar still inverted, place it over (*b*). Support the jar and flask in this position for ten minutes; then compare the results with (*a*).

(*C*) Fit up apparatus for preparing oxygen gas from manganese dioxide. As soon as the gas begins to be given off, connect the delivery tube with (*c*). Watch the effect of the oxygen upon the blood in the flask. Remove (*c*) and connect the delivery tube with (*a*). Compare the results of thus introducing oxygen upon the colour of the blood, in both (*c*) and (*a*). Note the time taken by the blood to attain an equally bright tint in the two cases.

VI.—The Effect on Blood of Carbon Monoxide Gas.

MATERIALS: *Fresh blood; ammoniated solution of carmine.*

APPARATUS: 1 *small flask; rubber tube; glass nozzle; gas jet.*

(1) Make a solution of 1 part of fresh blood to 100 parts of water. Measure with a pipette 5 c.c. of the solution into a test tube.

(2) Attach a short length of rubber tube fitted with a glass nozzle to a gas jet or Bunsen burner. Turn on the gas and allow it to pass into the test tube for a few seconds.

(3) Quickly close the test tube with the thumb to prevent the gas escaping, turn off the gas jet, and thoroughly shake up the blood solution with the gas. The *hæmoglobin* is thus thoroughly saturated with carbon monoxide, which is contained in coal gas to the extent of about 10%. Observe the characteristic pink tint, and compare it (*a*) with 5 c.c. of the normal blood solution in a similar test tube, (*b*) with a dilute solution of carmine, dissolved with the assistance of a little ammonia.

NOTE.—By careful dilution, the exact tint of the abnormal blood solution will be attained in the carmine solution, and will assist to impress the colour upon the mind. The chief sources of carbonic oxide gas are leakages of "water gas" or coal gas; the use of coke or of unlined cast-iron stoves for heating purposes; or down draughts from chimneys. It is a very virulent, narcotic poison. As little as 0·4 % may prove fatal, for the gas unites with the hæmoglobin of the red corpuscles and displaces the oxygen; the red corpuscles become unable to fulfil their function as oxygen carriers to the tissues, and failure of the chief nerve centres results.

The dangerous properties of this gas are seriously enhanced by the fact that it is odourless, and consequently impossible of detection by the sense of smell. "Water gas" contains from 25 to 40 % of carbon monoxide before combustion.

VII.—Dissection of a Sheep's Heart.

MATERIALS: *Sheep's heart, with pluck attached; water; quills; blue and red wool.*

APPARATUS: *Dissecting instruments; board.*

Observe the relative position of the heart and lungs when the mass is held up by the windpipe with the heart facing outwards (*Fig.* 29).

(*A*) Identify :—

(1) The uppermost or anterior end of the heart.

(2) The lower or posterior end.

(3) The outside surface, the ventral.

(4) The reverse side, the dorsal.

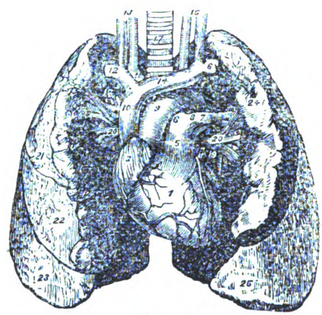

FIG. 29.

(*B*) Observe the stiff, cartilaginous rings of the windpipe, and the enlargement of the anterior end, *i.e.*, the *larynx*.

(*C*) Separate the soft, red tube which runs alongside and is attached to the dorsal surface of the windpipe; this is the gullet or *œsophagus*.

(*D*) Note any differences to be distinguished between the right lung and the left one.

(*E*) Compare the conical shape of the whole mass with the shape of the chest cavity, as shown in a skeleton.

(*F*) Place the mass on the table with the ventral surface uppermost, and proceed to examine the heart externally.

(1) The strong, fibrous membrane, within which the heart lies, is called the *pericardium*; observe how it extends over the large vessels at the base of the heart.

(2) Cut this bag or sac with scissors; watch for the escape of the *pericardial fluid* and examine the smooth, shiny, moist, inner surface of the pericardium.

(3) Notice the features which distinguish the exterior of the heart. The groove filled with fat, which runs obliquely across the surface of the heart, separates the two *ventricles*; above the groove, which circles round the top of the heart, lie the two *auricles*. These grooves mark externally the partitions (*septa*) which divide the heart internally into four chambers.

(4) Compare the width and thickness of the heart at the base and apex; also the length and convexity of the dorsal and ventral surfaces.

(5) Examine the two ventricles and note the differences to be detected by the eye as to size, colour, and position; by touch, as to texture and the thickness of the walls. The right ventricle forms nearly all the front of the heart when in its normal position.

(6) Observe that the greater part of the auricles lies behind the big vessels which spring from their upper surface; compare them in size, colour, and appearance with the ventricles.

(7) The flat, crinkled bags, which appear on the ventral surface of the base of the heart are the *appendages of the auricles*.

(*G*) Study the blood vessels attached to the heart.

(1) Turn the heart to the left, raise the right auricle and find the *aorta* issuing from the *left* ventricle. It is a large vessel, with firm, thick walls of a light yellow colour, and empty. Grasp the vessel and lift the heart, in order to show its elasticity, a property which allows it to expand as blood is forced into it by the contraction of the ventricles,

and also enables it to propel the blood forward; this elasticity characterises all arteries.

(2) Turn the heart to the *right* and find the *pulmonary artery*, which rises from the base of the right ventricle between the two auricles.

(3) Carefully dissect away the fat at the base of the heart, and then trace the two short *pulmonary veins* which leave the lungs and enter the left auricle; these vessels are more difficult to distinguish than are the arteries, in consequence of their venous characteristics, the thin walls being less elastic and more collapsible than those of arteries.

(4) Turn the heart to the *left* and find the large, flabby, red-lined vessel (the superior *vena cava*) as it enters the anterior surface of the right auricle; discover also the *inferior vena cava* which enters posteriorly.

(5) Keeping the heart and lungs in position, carefully separate the aorta from the pulmonary artery, and trace its course as far as possible, as it arches over and runs down between the two lungs; gently clear away any fat or other tissue attached to it, and take note of any vessels which spring from it.

(6) Slit up the aorta with the scissors to its origin in the left ventricle, and look for the *coronary arteries* which arise just beyond the *semi-lunar valves.* These arteries quickly break up into capillaries, which are distributed through and nourish the substance of the heart. The coronary arteries, capillaries and veins constitute the shortest blood circuit in the body (*see* VIII. (*C*), *pp.* 130-131).

(7) Trace the pulmonary artery and veins in a similar way, and cut the vessels off short at the conclusion of the operation.

VIII.—The Internal Structure of the Heart.

(*A*) Pass a quill, or a probe, into the inferior vena cava through the right auricle and out of the superior vena cava. Cut along the upper side of the probe and examine the inside of

the auricle and veins. Observe the size of the auricle, and, at the extreme left, look for the mouth of the coronary vein. Pick out any clots which may be present, and slit the anterior wall, in order to expose the *muscular columns* within the auricular appendage (*Fig.* 30).

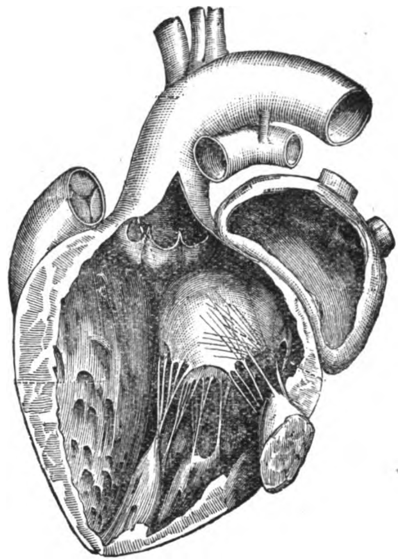

FIG. 30.

(*B*) Cut through the root of the aorta just above the top of the left ventricle. Find within the three membranous flaps called the *semi-lunar valves.* Pour a stream of water on them and observe how they will close the entrance to the left ventricle. Repeat the observation and experiment with the pulmonary artery, and compare it with the observations made on the model in IV. (*C*), NOTE, *pp.* 124-125.

(*C*) Cut the whole of the right auricular appendage away. Examine it carefully and endeavour to find the orifice of the coronary vein which discharges into this auricle. Look

down into the right ventricle. The three irregular-shaped valve-flaps to be seen hanging round the auriculo-ventricular orifice are the *tricuspid valves.*

To observe the action of the tricuspid valves, pin down the flap of the left auricle so that water may not enter the left half of the heart. Clasp the heart in the left hand with the ventral surface in the palm, and pour water from a jug through the right auricle into the right ventricle, at first very gently, then with more force. Watch the action of the valves. Empty the heart and fill it again; when the valves have risen, press with the fingers on the outside of the ventricle; note the effect. Repeat the experiment, but introduce the water through a tube, the nozzle of which passes between the valves, and observe how the water escapes.

(*D*) Empty the heart and examine the white cords (*chordæ tendinæ*) which control the action of the valves.

(*E*) Pass the finger to the bottom of the right ventricle and carefully cut through the wall of the ventricle in two directions to form a flap. Raise this, and study the number of valves, their arrangement, the conical elevations of the *papillary* muscles to which the *chordæ tendinæ* are attached.

(*F*) Examine the left auricle; find where the pulmonary veins enter; cut away the lobe and examine the inner surface. Repeat the experiment detailed in (*C*) to prove, in this case, the action of the *mitral valves* between the left auricle and left ventricle; examine their size, shape, number, and arrangement.

(*G*) Cut open the left ventricle by following the external groove (*Fig.* 31, *p.* 132). Note:—

(1) The strong muscular columns.

(2) The strong papillary muscles.

(3) That the mitral valve, though ending in two main flaps below, is continuous at the top.

(4) The chordæ tendinæ passing from the apices of the papillary muscles to the mitral valve.

(5) The muscular bands in the lower internal surface.

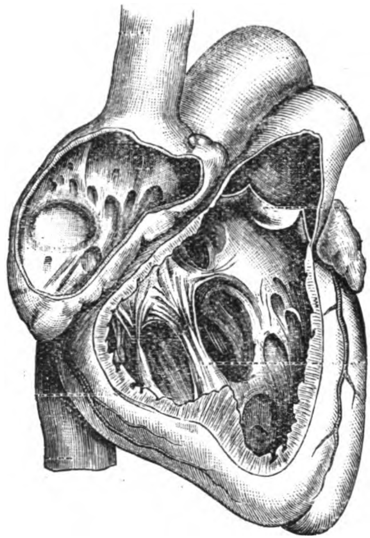

FIG. 31.

(6) The smooth, glistening lining.

(7) The muscular partition which separates the right from the left side of the heart.

(8) The position of the opening of the aorta. Compare the two ventricles on each point, and enumerate the differences to be observed.

NOTE.—The butcher must be cautioned to supply the sheep's heart with "pluck" attached, as far as possible uninjured, and with the tubes cut long; otherwise it is difficult to distinguish the pericardium or to identify, satisfactorily, the characteristics of the blood vessels.

To illustrate the formation of the pericardium, *i.e.*, that it is a double membrane, of which one part closely covers the heart, the other forming the sac (the two being continuous

above at the base of the heart), Professor L. Hill suggests that the hand be placed in a sock which has the foot turned inwards, as is usual when it returns from the wash; the hand will thus be covered by a double bag.

It must be impressed on the pupils that, in man, there are *four* pulmonary veins, not *two* only as in the sheep.

Thin splinters should be used as probes; these should be passed through the vessels as they are identified into the chambers of the heart. Assistance in the case of young students is occasionally derived from attaching red or blue thread to the probes in order to demonstrate the course of the blood through the heart.

Draw attention to the *corpora arantii*, those little thickened points in the middle of the free border of each semi-lunar valve which fill up the small triangular opening that would otherwise be left between the valves.

To keep a sheep's heart for observations which cannot all be made at one lesson, wrap it first in wet and then in dry paper, storing it in a cool place. The length of time during which it can be kept depends naturally on the season of the year and the atmospheric conditions, but when "cold storage" is available, there is practically no limit to the time during which carefully-handled specimens may be preserved.

VIII.—THE SYSTEMS OF THE BODY AND THEIR FUNCTIONS (*contd.*).

(C) THE RESPIRATORY SYSTEM.

Mechanical and chemical changes associated with Respiration. The vital capacity. Dissection of a sheep's lungs.

I.—Observations on Respiratory Movements.

(*A*) Place one hand on the chest and the other on the back between the shoulder blades. Breathe in and out slowly. In what direction does (1) the chest, (2) the back move?

(*B*) Place both hands lightly on the sides of the body, over the lowest ribs. Breathe in and out slowly. In what direction does the chest move?

(*C*) Lay the hands lightly on the chest, count the number of respirations in a minute, (1) when at rest, (2) after rapid exercise.

(*D*) Pass a tape measure round the chest just under the arms, and record your measurements (1) when breathing naturally, (2) after a full inspiration, (3) after a forced expiration. What do the results indicate?

NOTE.—It will be advisable to repeat (*D*) several times in order to secure an accurate average, as excitement and inexperience will probably vitiate the first trials. In an adult, the difference between (2) and (3) should be at least three inches, though this depends largely on physical development and judicious training.

II.—Demonstration to Illustrate the Vertical Enlargement of the Thorax.

MATERIALS: *Elastic rubber tissue; rubber-bands; toy rubber balloon; rubber tubing.*

APPARATUS: *Large lamp chimney or bell-jar; rubber cork with* 2 *holes; pinch-cock.*

Take a large lamp chimney or bell-jar. Make the lower and larger end air-tight by covering it with a piece of elastic rubber tissue, held in place by a firm rubber-band. The experiment is more conveniently performed if the piece of rubber tissue be cut of a sufficient size to allow a small marble to be first tied pudding fashion into its centre, before it is stretched over the bottom of the lamp chimney or bell-jar. Fit two pieces of glass tubing (*a*) and (*b*), bent at right angles, into a rubber cork, which must accurately fit the upper end of the lamp chimney or bell-jar; (*a*) should extend to the middle of the chimney, and must have a toy rubber bladder firmly attached to the lower end; (*b*) should only extend slightly below the cork. Fix a short length of rubber tubing to the external opening of (*b*).

When the apparatus is fitted up, partially exhaust the air in the vessel by sucking, and quickly close (*b*) with a pinch-cock. The pressure of the atmosphere outside the

chimney or jar thus becomes greater than the air which surrounds the bladder within. Notice how this greater external pressure forces air down the tube into the bladder, which at once expands. Test also, with the fingers, whether the rubber covering the bottom of the vessel has become somewhat concave from the same cause, *i.e.*, inequality of air pressure within and without the chimney or jar. Then pull the covering downwards by grasping the marble; what is the result of thus increasing the size of the cavity within the vessel?—does the bladder expand or shrink? Loose the marble with some force; watch the effect on the bladder. Repeat the experiment several times, and assist yourself to an explanation of your observations and of their application to the respiratory mechanism of the body by comparisons with your sensations when conducting the tests in I. (*A*), (*B*), (*C*) and (*D*).

Note.— Naturally a rigid glass cylinder allows of no movement, either from side to side or forward and backward, such as takes place in the walls of the thorax, and nothing corresponds in the body to (*b*) in the model; for in animals with lungs, their chest cavities are free from air, only the lungs inspire and expel it. No rubber covering either can become dome-like, as does the diaphragm in breathing; because the pronounced convexity it assumes within the thorax is caused by the anterior pressure of the abdominal organs, whereas in the model atmospheric pressure only is at work.

It is desirable to impress clearly the fact that the respiratory movements are mainly the result of variations of atmospheric pressure within the thorax. The lungs are kept distended by the normal atmospheric pressure acting down the trachea, which keeps the outer wall of each lung firmly pressed against the inner wall of the thorax. If the thorax be enlarged, as it is in inspiration, air must rush in to prevent the formation of a vacuum between the two pleuræ, which would otherwise result from diminished pressure when the cavity of the thorax expands.

In this model, the chimney represents the cavity of the *thorax*. The rubber-covering replaces the *diaphragm*, the the toy balloon represents the *lungs*, and the glass tube, to which it is attached, the *trachea*. Thus the results of

altering the size of the cavity, and coincidently the air pressure within the chimney or jar by lowering or raising the "diaphragm," illustrates, only very roughly, a somewhat similar process in the thorax.

When the diaphragm and the external intercostal muscles contract during the muscular effort of inspiration, the chest cavity becomes wider and deeper, because the anterior ends of the ribs are pulled upward and outward, the sternum is pushed forward and the diaphragm depressed posteriorly. Air rushes in to fill the resulting greater space, in which pressure is diminished, and so expands the elastic lungs (as it does the bladder in the lamp chimney), until the pressure of the atmosphere within and without is equalized. Immediately the muscles relax, the diaphragm is pushed up by the abdominal organs below, while the ribs and sternum drop downwards. This contraction of the thoracic cavity naturally increases the air pressure within the lungs; air is forced out to relieve this pressure and so again equalizes the pressure—the two conditions constantly alternating in normal respiration, which is partly diaphragmatic, partly costal.

In *quiet* respiration, the expansive movements are more pronounced in the lower than in the upper part of the thorax. In *laboured* or *forced breathing* the greatest extent of movement takes place in the upper part of the chest. In *extraordinary inspirations*, associated with violent exertion or illness, many muscles are pressed into service which are usually but little used. Even those of the face and larynx come into play.

The peculiarities of chest expansion in inspiration at different ages and in various persons are usually classified as follows:—

(1) In children, respiration is described as *abdominal*, because the diaphragm, which plays a very prominent part, flattens as it contracts, presses down on the intestines and pushes forward the abdominal walls, of which the movements are very manifest.

(2) In women, the prevalent type of breathing is known as the *superior costal*, the chief expansion occurring in the upper part of the thorax; whereas

(3) In men, where the diaphragm, chest, and sternum are all subject to wide movements, breathing is described as of the *inferior costal* type.

III.—Make a Model to Illustrate the Dorso-ventral Enlargement of the Thorax observed in I. (*A*), (*B*). (*Adapted from Bertha Brown's "Physiology for the Laboratory."*)

MATERIALS: *Stiff cardboard; paper fasteners; hooks and eyes; rubber bands; sharp knife; measuring ruler.*

Cut seven strips of stiff cardboard to the following dimensions:—

(1) One piece 2 cms. × 20 cms. ($\frac{3}{4}$ in. × 8 in.)

(2) One piece 2 cms. × 15 cms. ($\frac{3}{4}$ in. × 6 in.)

(3) (4) (5) (6) (7) Five pieces, each 2 cms. × 8 cms. ($\frac{3}{4}$ in. × 3 in.) (*Fig.* 32).

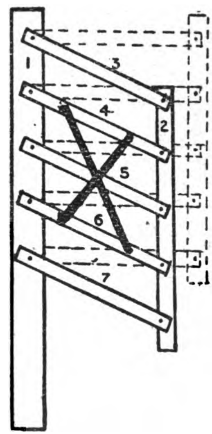

FIG. 32.

Let (1) represent the spine and (2) the sternum. Fix (3) (4) (5) (6) and (7), which represent ribs, to (1) and (2), by means of strong paper-fasteners, so that they are moveable at both ends. Take two short rubber bands and fasten them obliquely, by means of hooks or drawing pins, near the ends of (4) and (6), the one downwards and forwards, the other downwards and backwards, so that they cross each other, and are just on the stretch when fixed. These represent the two layers of intercostal muscles. Raise and lower (2), carefully taking note of the effects upon the tension of the rubber bands. What light does this model throw upon the mechanism by which the capacity of the thorax is increased in inspiration and diminished in expiration?

NOTE.—The change in the position of the ribs and the pull of the muscles are often better comprehended after constructing this model, though it is important for pupils to understand that the relaxation of the chest-muscles, in ordinary respiration, is largely the outcome of elastic recoil. Only in forced expiration do the internal intercostal muscles assist in depressing the ribs and sternum, when they receive much assistance from the abdominal muscles.

Attention should be directed to the lateral enlargement which occurs simultaneously with the dorso-ventral one, on account of the hoop-like curvature of the ribs, for the ribs may be said to bulge outwards as they rise, instead of remaining straight as in the model.

IV.—Make a Record of the Changes which Air undergoes in the process of Respiration.

MATERIALS: *Small mirror or small slate; water;* 250 *c.c. lime-water; fine earth or charcoal.*

APPARATUS: *Thermometer;* 3 *tumblers; glass tube; c.c. measure; large glass vessel;* 3 *glass vessels graduated in size.*

(*A*) Note the temperature of the room; hold a thermometer close to the lips and expire upon its bulb several times in quick succession; observe any change in its register.

(*B*) Expose a small mirror, dry slate, or polished metal article to the air of the room for some minutes. Then breathe on the surface of each, or all, and record any evidence of a change which this experiment shows the air to have undergone while in the lungs.

(*C*) (1) Expose a tumbler half full of lime-water to the air in the room for half-an-hour; observe any indication of change in its appearance.

(2) Exhale three or four deep breaths into the tumbler through a glass tube; give proofs of the nature of the change now visible by reference to "AIR," IV. (*b*), *page* 54.

(3) Measure 100 c.c. lime-water into each of two small tumblers of the same size, (*a*) and (*b*).

Expire *naturally* into (*a*) for 30 seconds through a glass tube. Expire *very deeply* into (*b*) for the same length of time. What difference in result is to be observed between the two? How does this illustrate the advantages to the body of occasional deep breathing or of very active exercise?

(*D*) Stir some powdered earth or charcoal, into a very large vessel of water (*a*). Fill a quite small vessel full of water (*b*). Empty the contents of (*b*) quickly into (*a*), and, as rapidly

as possible, dip the small vessel just beneath the surface of (*a*) and bring it out refilled. Pour this out, refill (*b*) with clear water, and repeat the above process several times. Observe to what extent the contents of (*b*) purify (*a*). This procedure may be compared roughly with the renewal of air in the lungs during quiet, *tidal* respiration, when the amount of pure air inhaled is relatively small, and aeration of the lungs is carried on chiefly by the partial diffusion of the gases contained in the inspired air. The exchange between the pure and impure takes place in the lungs, as in the jar, where the material is least vitiated; for it is here, where the constant addition is made of a fresh supply, that impurities are most diluted.

Substitute a much larger vessel for (*b*), and after repeating the process of rapidly pouring in and dipping out as previously directed, consider whether the results on (*a*) might be compared with the effect on the lungs of deep, full respirations.

Again repeat the process, but employ a third vessel of still greater capacity in place of (*b*). The effects on (*a*) of this increased dilution of its impure contents may now be roughly compared with the inspiration of *complemental* air and the expiration of *reserve* air.

NOTE.—The rise of temperature in expired air, and the presence in it of moisture and of carbon dioxide gas can be clearly demonstrated, and give opportunities for emphasis to be laid on the discomfort and undesirable effects which ensue when polluted air is constantly inhaled. The proportion of water-vapour in the air will be dealt with under "Ventilation," but the fact cannot be too often impressed that fidgets, restlessness, weariness, and oppression are the immediate effects of too high a percentage of water-vapour in the air of a room.

No test is given for the presence of organic matter in expired air, because very little is present in the absence of decayed teeth, or of throat or stomach disorders; healthy lungs being sterile as regards micro-organisms. The organic matter which pollutes air is chiefly that given off by the skin, clothes, putrefying dust, etc. The reasons why the less injurious carbon dioxide gas is used as an index to organic impurities should be mentioned.

"As a rule, no actual discomfort in breathing is experienced until the carbon dioxide accumulates to 40 parts per 10,000, or to 10 times the normal amount. This is probably due to its *solubility* and to its interference with the respiratory exchange, since the interchange of gases is influenced by their *partial pressures*. Each gas forming part of a mechanical mixture exerts a partial pressure proportional to its percentage of the mixture. For example, if atmospheric air, containing 20·81 % of oxygen, is at 760 millimetres (30 in., more correctly 29·922 in.) barometric pressure, the partial pressure of the oxygen would be $\frac{20.81}{100} \times 760 = 158.15$ millimetres. The following partial pressures of oxygen and carbon dioxide in inspired air and in the lung-cells show the extent of variation in different parts of the respiratory tract:—

	Inspired Air.	Lung-cells.
Oxygen	158·15 mm.	122 mm.
Carbon dioxide ..	0·30 mm.	38 mm.

Gas will always tend to diffuse from the region of highest to that of lowest pressure. Hence the reason for the great influence of pressure in causing the diffusion of oxygen from the inspired air into the lung-cells and for the converse movement of carbon dioxide." (*Richards & Woodman's "Air, Water, and Food," pp.* 12-13.)

Experiments, (*C*) (3), and (*D*), serve to illustrate the importance of *deep* respirations and the relatively small amount of diffusion and aeration of the blood which attends shallow breathing. In the course of such breathing, the air in the lungs receives about one-eighth of its volume of fresh air at each inspiration, about one-ninth being exhaled at at each expiration. Hence one great use of active exercise which induces deep breathing, as well as of occasional pauses during sedentary occupation, for the purpose of making a few deep inspirations and expirations. Breathing directly aids the flow of lymph by the pressure of the descending diaphragm upon the main lymph duct; it also assists the circulation of the blood, as well as its purification, so that its nutritive influence is of the first importance.

V.—A Demonstration on Lung Capacity.

(*A*) Stand up and breathe naturally and regularly. Extend one arm horizontally and mark the rhythm of such breathing by gently raising and lowering the arm and hand in time with each inspiration and expiration. It will thus act as a gauge,

which, by the exercise of a little care, will suffice to illustrate and measure the observations required in this and the following demonstrations. *Tidal* air is the name given to the amount of air taken in and given out during such normal breathing; it averages 300 to 500 c.c. (nearly 20 to about 30 cubic in.), according to the age, sex and physical development of the individual.

(*B*) Continue to breathe as in (*A*), but at the end of a few inspirations proceed to 'breathe in' for as long a time as possible, raising the hand and arm horizontally throughout this prolonged inspiration. They should rise to about five times the height in (*A*). The *complemental* air thus inspired averages 1,600 to 1,950 c.c. (100 to 120 cubic in.).

(*C*) Breathe normally as in (*A*), marking the rhythm as directed. At the end of a few expirations continue to expel as much air as is possible from the lungs, lowering the hand during the process. The average amount of *reserve* or *supplemental* air thus driven out is calculated to be 1,500 to 1,625 c.c. (100 to 108 cubic inches). The movement of the hand can be regulated to assist in gauging the amount of air expired.

NOTE.—Ordinary *tidal* respiration equals about 500 c.c. (from 20 to 30 cubic in.). It is the amount of air inspired and expired during quiet breathing. *Complemental air* represents a deep inspiration of about 1,500 c.c. (100 cubic in.); an amount of air that can be, but seldom is, inspired. *Reserve* or *supplemental air* signifies a similar amount of air which can be, but seldom is, expelled by a deep expiration. *Residual air* is that residue in the lungs which cannot be expired during life. It amounts to about 1,500 c.c. (75 to 100 cubic in.).

The sum of the tidal, reserve, and complemental air amounts to about 3,500 or 4,000 c.c. (230 to 250 cubic in.). It is a measure of what is known as the *respiratory* or *vital capacity*, which varies according to height, age, sex, and weight; though as the influence of this last is so much less manifest and considerable than that of height, and does not apparently come into play under a weight of about 75 kilos. (160 lbs.), no reference is made to it in the calculations required of the pupils.

VI.—The Vital Capacity.

MATERIALS: *Water; rubber tubing.*

APPARATUS: *Gallon jar; basin; glass tubing; rubber cork with 2 holes; c.c. measure.*

(*A*) Proceed to calculate from the following data what your own *vital capacity* should be. Note that height, age and sex must be taken into most careful account. At a temperature of 15·4°C. (60°F.) the average respiratory or vital capacity of a healthy person, 34 years of age, 170 cms. (5 ft. 7 in.) high, should be 3,500 c.c. (225 cubic in.). This amount is therefore usually accepted as the average standard by which individual capacities are gauged. (1) height, (2) age, and (3) sex are the chief qualifying factors.

(1) *Height.* For every inch of height *above* 170 cms. (5 ft. 7 in.) the vital capacity is increased, on an average, 128 c.c. (8 cubic in.), and for every inch *below* this height it is diminished by the same amount.

(2) *Age.* The vital capacity increases annually from about 14 to 34 at the rate of 80 c.c. (5 cubic in.); from 35 to 65 it diminishes at the annual rate of about 24 c.c. ($1\frac{1}{2}$ cubic in.).

(3) *Sex.* The vital capacity of an adult woman compared with that of a man of the same age is as 7 to 10.

Each pupil should find his exact height, and add to, or deduct from, the standard vital capacity given above, 128 c.c. (8 cubic in.) for every 2·5 centimetres (1 in.) of deviation from 170 cms. (5 ft. 7 in.). If less than 14 years of age, a further deduction of 80 c.c. (5 cubic in.) must be made for each year below that age. For older students the calculations will be somewhat further complicated by a third factor, the relative proportions between the sexes.

Example. A boy of 12 years old is 150 cms. (5 ft.) high. A deduction of 896 c.c. (56 cubic in.) must consequently be made, in respect of his height, from the average vital capacity of 3,500 c.c. (225 cubic in.) of an adult of thirty-

four, and a further deduction of 160 c.c. (10 cubic in.) in respect of his age. The boy's vital capacity *should* theoretically therefore amount to 2,444 c.c. (159 cubic in.).

(*B*) Test the accuracy of any theoretical calculation of individual vital capacity by the following experiment:—

Procure a large jar, of which the capacity is about 4,000 c.c. (1 gallon), and fill it with water. Fit to this a rubber cork pierced with two holes, (*a*), (*b*). Pass a short piece of glass tubing through (*a*), and through (*b*) pass a long piece, which should reach almost to the bottom of the jar; connect to its external end a sufficient length of rubber tubing to hang over the brim of an empty basin, placed beside the jar. Take the deepest possible inspiration, and do not expire until the lips are in contact with the short tube in (*a*). Then expire through the tube as forcibly and for as long a period as possible. Measure the water driven out of the jar by the breath. The amount of water expelled into the basin will represent the amount of the respiratory or vital capacity. To attain a fairly accurate result, repeat the experiment several times and on two or three occasions, until, with practice, the quantity of water expelled and measured amounts to about the same on three or four successive trials; this quantity may be then fairly assumed to represent the vital capacity of the individual.

VII.—Dissection of a Sheep's or Pig's Lungs.

MATERIALS: *Sheep's or pig's lungs; pair of bellows; rubber tube; water.*

APPARATUS: *Dissecting instruments; board; large glass tube; pinch-cock: small bowl.*

(*A*) Take the lungs and trachea provided, and notice their different parts:—

(1) The size, shape, colour, texture and number of lobes in each lung, and the smooth, moist, glistening *pleura* with which they are invested.

(2) The size, shape, colour and structure of the trachea. Distinguish the *epiglottis* at the root of the tongue, and the *glottis*, a narrow chink within the *larynx* (*Fig.* 33).

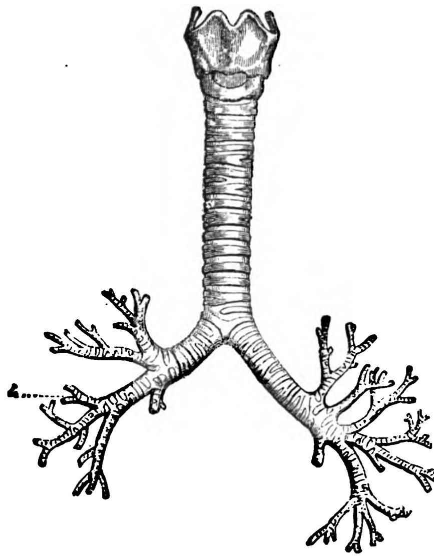

FIG. 33.

(*B*) Insert the nozzle of a pair of bellows (or, preferably, a large glass tube) into the trachea, or, if this or either lung be injured, into one of the bronchial tubes; tie it very firmly, connect the glass tube with the bellows by a short piece of rubber tubing and proceed to inflate the lungs. Close the rubber tube with a pinch-cock, and hold up the inflated lungs for further examination.

(1) Compare the conical shape of the mass with the shape of the thorax.

(2) Observe how nearly the lungs surround the heart.

(3) Note the concave lower surfaces which follow the outline of the convex upper surface of the diaphragm.

(4) Trace the groove in their dorsal surface into which the spine fits.

(5) Look at the marked difference between their ventral and dorsal appearances.

(6) Puncture a portion of the lung, observe the instant escape of air.

(*C*) Cut off the larynx and examine the trachea.

(1) Its rings of cartilage. Note how these are connected posteriorly, and to what class of tissue the gullet adheres.

(2) Split open the trachea, which will probably contain some mucous (wash this out with a stream of water, or remove with mops of cotton-wool held in forceps), and trace its division into the *bronchial tubes*.

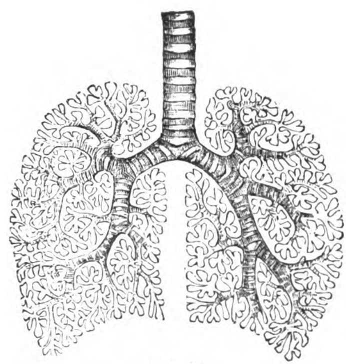

FIG. 34.

(3) Cut along one of these, and examine its structure. Clear away the external lung tissue with the handle of a knife or of a scalpel, in order to trace the many sub-divisions of the bronchi, and note also the *lymphatic glands* (small, oval, brownish masses), buried in the connective tissue.

(4) Cut across a portion of one lung and examine the divided surfaces (*Fig.* 34). Trace:—

(*a*) The *bronchial tubes*, kept open by the plates of cartilage in their walls.

(*b*) The *arteries*; white, circular, and open.

(*c*) The *veins*; blue, collapsed, and flaccid.

(*D*) Separate two small pieces, (1) and (2), of the lung. Place (1) on the surface of a bowl of water. Squeeze (2) tightly close to the ear. How does (2) assist to explain (1)?

NOTE.—Lung tissue floats because it always contains some air. If the air sacs are compressed to expel the air, so also are the minute bronchial tubes; but these latter exert a contrary influence, and thus all the residual air can never be entirely expelled from the lungs.

VIII.—THE SYSTEMS OF THE BODY AND THEIR FUNCTIONS (*contd.*).

(D) THE OSSEOUS SYSTEM.

FIG. 35.

Bones and joints—their shape, structure, composition and mechanics.

I.—Observations on the Shape of Bones.

(*A*) Note peculiarities in the shape and the relative position of the different bones in the body (*Fig.* 35).

(*B*) Devise movements and postures by which to identify the following bones in the body, and classify them as

(1) long, (2) flat, (3) irregular. The skull; the spinal vertebræ; the ribs; the collar-bones or clavicles, and the shoulder-blades or scapulæ which form the shoulder girdle; the chest-bone or sternum; the hip bones (or *ossa innominata*) which, with the *sacrum*, form the pelvic girdle; the limbs, *i.e.*, the arms and legs.

(*a*) *The Arm.* The long bone or *humerus*; the two bones of the fore-arm, the *radius* and the *ulna*; the wrist, formed by a number of small bones, the *carpus*; the hand, formed of the *metacarpal bones*; the fingers, each formed of three *phalanges*, and the thumb, which has two (*Fig.* 36).

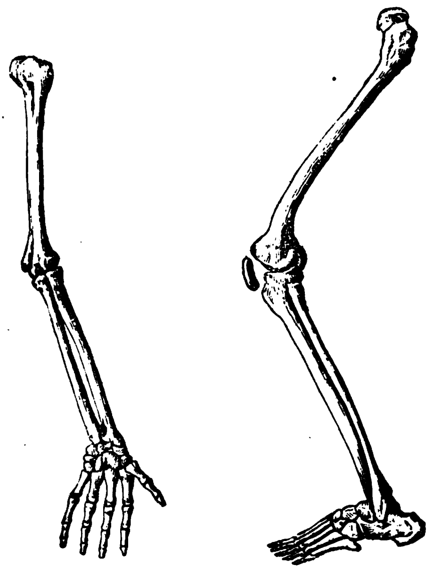

FIG. 36.

(*b*) *The Leg.* The thigh bone or *femur;* the two leg bones, or the *tibia* and *fibula*; the foot, formed of short *tarsal* and *metatarsal* bones; the toes, each formed of three *phalanges*, except the great toe, which has only two.

NOTE.—Each pupil should trace the *irregular processes* of the vertebræ as they can be felt on running the finger down the spine; the hooped curve of the ribs; the shallow, flat sternum; the line of the clavicles; the broad, flat scapulæ, with their horizontal ridges where they join the clavicles at the outer point of the shoulder.

To observe the *pronation* and *supination* of the radius and ulna, direct the pupil to rest the elbow and fore-arm on a flat surface, keeping the little finger and outer side of the

hand in contact with the table to serve as a hinge. If the hand be now turned to and fro, the rotation of the lower end of the radius round the stationary ulna can be distinguished.

In *pronation*, when the back of the hand is uppermost, the radius turns on its own axis above and round the ulna below, until its lower portion crosses the ulna, on the inner side of which its lower end will lie.

In *supination*, when the palm of the hand is uppermost, the radius lies parallel with the ulna, with its lower end to the outer side of the ulna. The movement can be advantageously studied on a skeleton (*Fig.* 36).

The bones of the carpus are not easily felt, but their function in permitting free movement of the hand can, of course, be demonstrated. The upper crest of the hip bone can be traced as it runs forward from the spine, and its identification affords opportunity to refer to that part of the pelvic girdle formed by the sacrum. The rotation of the thigh bone can be felt in the upper part of the thigh if the leg be extended when sitting, and the foot rolled while the heel is resting on the floor.

It is advisable to demonstrate to the class the flexibility of the foot; its normal shape, and the fact that, if properly developed, its bones form an arch and constitute a strong, elastic support for the body, of great value in preventing jars to the spinal cord and the brain. If the feet of two or three members of the class be dipped in warm water and pressed on slates or on chalked boards, the supporting piers of this arch will be printed on the surfaces, and the extent of the arches will be observed to vary; in a flat foot the arch is more or less completely obliterated.

II.—Observations on the Structure of Bones.

MATERIALS: *Fresh specimens of bones (sheep or ox); portion of spinal column well boiled; good hand-lens.*

(*A*) Study the structure of a long bone from a fresh specimen (sheep or ox).

(1) Its external appearance.

(*a*) The *shaft*, with its upper and lower articular surfaces.

(*b*) The delicate *periosteum*, or fibrous covering; this may be stripped off with forceps if the bone be soaked for some time in water.

(*c*) The rough *prominences* at the ends for the attachment of muscles and ligaments.

(*d*) The smooth *grooves* in which the blood-vessels lie. Endeavour to trace one of these, until it ends in an opening which passes into the bone.

(*e*) Examine the surface with a good hand-lens to find the numerous minute openings by which the small blood-vessels enter the bone.

(2) Its internal appearance.

(*a*) The hard or compact bone of the hollow shaft.

(*b*) The spongy bone at both ends with its supporting "struts and stays" of bone spicules.

(*c*) The medullary cavity which does not extend into the articular enlargements.

(*d*) The marrow; yellow, with fat in the shaft, red and vascular in the spongy bone.

(3) Study of typical vertebræ.

(*a*) Take a portion of the spinal column of an ox or sheep, which has been well boiled, so that the muscles and ligaments can be easily removed. Note:—

(1) The body or round mass of bone in front of each vertebra.

(2) The arch formed by the two pillars which spring from the body and meet behind, thus forming a ring through which passes the delicate spinal cord.

(3) The various processes which project outwards from the arch.

(*a*) The long *spinous process* which projects backwards from the middle of the arch and slopes downwards to protect the arch of the vertebra below.

(*b*) The two *transverse processes* which project outwards from where the pillars of the arch spring from the body.

(*c*) The four short *articulating processes* which project from each arch, two above and two below, by means of which the vertebræ articulate with each other.

(*d*) The small openings at the sides of the arch for the passage of blood-vessels and nerves.

(*e*) The cushions of white elastic cartilage between each pair of vertebræ.

(*B*) (1) Take the first two cervical vertebræ (which have been previously boiled), of a sheep or an ox, the *atlas* and the *axis*. Observe that the atlas is ring-shaped and has no proper body. Note the strong fibrous ligament which separates it into two rings—one small, the anterior, and one large, the posterior, and the smooth surfaces upon which the skull rests, which enable the head to nod to and fro.

(2) Examine the mechanism by which the *odontoid process* of the axis serves as a pivot for the atlas to turn upon, by projecting into the anterior ring of the atlas.

(3) Remove the surrounding tissues, making careful observations of the ligaments which control the movements of the skull.

III.—The Mechanics of Bone Structure.

MATERIALS: 2 *sheets stiff paper; rubber bands; weights; short length of lead pipe; hammer;* 2 *small, thick rubber pads.*

(*A*) (1) Take a sheet of paper and roll it into a cylinder about an inch in diameter; hold it in shape by means of rubber bands, and support it in a horizontal position. Suspend a weight from the middle of the cylinder; find what weight can be suspended before it gives way.

(2) Take a similar sheet; roll it into a solid bar; support, and load as before. Notice the results in the two cases, and the advantages which accrue, where weight has to be supported, of forming the same bulk of a similar material into a hollow rod rather than a solid bar.

(*B*) *To illustrate the function of the Intervertebral Discs*, take two short lengths of lead pipe, (*a*) and (*b*), about 2·5 cms. (1 in.) in diameter. Place (*a*) on a board, and strike with a hammer. Place (*b*) also on a board, but before striking it with the hammer, isolate it from the board and protect it from the hammer by putting it upon a small, thick rubber pad, and placing another one on the top of it. (Pieces of ordinary india-rubber, such as are used for erasing, answer well; they should measure about 5×5 cms. (2×2 in.). Notice the different sensations experienced by the arm which wields the hammer and the different results upon the lead; the shock in the latter case is reduced by the elastic rebound of the intervening pads.

IV.—The Chemical Composition of Bone.

MATERIALS: *Small fresh bones (lamb or chicken); hydrochloric acid; water.*

APPARATUS: *Small saucepan; basin; glass jar; evaporating dish; iron spoon; wire gauze; china dish; balance; Bunsen burner; sand-bath; retort stand.*

(*A*) Weigh a small, fresh, long bone, and place it to soak for seven days in a jar of dilute hydrochloric acid (1 in 7). Take it out, rinse well, and observe whether the acid has changed the form, size, weight or character of the bone. Of what familiar substance does its consistency and texture remind you? Pour some of the liquid into an evaporating dish, and heat gently until the liquid has disappeared. Prove the nature of the substance left, whether animal or mineral matter, by dividing it into several portions, and subjecting them respectively to the tests for proteid, carbohydrates and mineral matters given in "GENERAL CONSTITUENTS OF THE BODY," *pp.* 165 *et seq.*

NOTE.—It is difficult to calculate the exact time required to dissolve the mineral matter in a bone; it depends upon the size, age, and character of the specimen employed.

The bones of fowls, or young rabbits, can be prepared in a few hours, especially if nitric acid, diluted with four parts

of water, be used. Few demonstrations prove more impressive than the tying of a bone into a knot after decalcification; for this purpose the rib of a sheep, or the leg of a fowl, answers well.

The recovery of the dissolved mineral matter (by evaporating the acid which holds it in solution), constitutes a useful conclusion to the experiment; as it brings forcibly into notice the very large proportion (about 67 %) of lime salts present in bone substance.

(*B*) Take several pieces of fresh bone. These may be easily procured from the butcher. Place them in a saucepan with sufficient water to cover them; cover the contents of the saucepan and stew for several hours, adding just sufficient water, when necessary, to prevent burning. Remove the bones and pour the liquid into a basin; set aside to cool. When cold the liquid should be set into a jelly, as a result of the extraction of the gelatine present in the bones by exposure to moist heat. If the bones be those of a young animal more gelatine will be present; consequently the process of extraction will be more rapid and the product a thicker gelatinous mass than when old bones are employed.

(*C*) Weigh a piece of clean bone. Record the weight, and place the bone in an iron spoon, securing it from falling out by covering with a piece of wire gauze firmly fixed with wire. Insert the spoon into the middle of a red-hot fire, and watch the changes undergone by the bone. When it becomes white, withdraw the spoon from the fire; cool it, then weigh the brittle, crumbling remains of the bone. Place the fragments in a china dish and add strong hydrochloric acid. The carbonate of lime, of which the residue is largely composed, will effervesce with the acid, carbon dioxide being formed and escaping in bubbles.

NOTE.—The familiar smell associated with the burning of bones is caused by the oxidation of the tissues and fat; the black coloration shows the presence of carbon, which is also oxidized if exposed to a sufficiently high temperature. The weight of the bones should diminish about one-third.

V.—Observations on Joints.

MATERIALS: *An articulated skeleton; freshly killed rabbit;* 2 *fore-legs of lamb or sheep.*

APPARATUS: *Dissecting instruments and board.*

(*A*) Identify as many joints as possible in the body and classify them under the following heads :—

(1) *Perfect, or Moveable.*

(*a*) Ball and socket.

(*b*) Hinge.

(*c*) Pivot.

(*d*) Gliding.

(2) *Imperfect, or Immoveable.*

(*B*) Illustrate the various kinds of bodily movements permitted by joints.

(1) *Angular* (of which there are four varieties).

(*a*) *Flexion.* Touch the top of the head with one hand. The arm is now flexed, or bent.

(*b*) *Extension.* Try, while sitting on a chair, to reach an object on the floor without stooping. The arm is now extended or straightened.

(*c*) *Adduction.* Move the thumb in towards the palm of the hand. It is now adducted, or drawn *towards* the middle line of the body.

(*d*) *Abduction.* Stretch the thumb out away from the hand as far as possible. It is now abducted, or moved *away from* the middle line of the body.

(2) *Coaptation.* This is a form of movement, difficult to demonstrate, in which the articular surface of one bone travels over that of another, as a wheel rolls along over the ground; the best illustration is found in the movement of the knee-cap (*patella*) upon the end of the thigh-bone (*femur*) (*Fig.* 85, *page* 146).

(3) *Circumduction.* Cause the thigh-bone to circle round an imaginary axis; the leg is then circumducted.

(4) *Rotation.* Swing the arm round from the shoulder on its own axis; it is thus rotated.

(*C*) Examine the joints in an articulated skeleton, and, if possible, compare them with those in a fresh specimen of a rabbit. Note the provision made to limit movement by bony prominences, which lock the bones within the joint. Ligaments also are arranged to check excessive movement.

(*D*) Study the hinge-joint in the fore-leg of a lamb or sheep, which should be cut off about two inches above, and the the same distance below, the knee. Examine one specimen preserved whole, and another divided longitudinally; compare with the arm of a man.

(1) Cut away all fat and muscle; expose the ligaments and find their uses.

(2) Observe how the tendons attach the muscles to the bone.

(3) Pierce the joint with the point of a knife. The thin fluid which exudes is the *synovial fluid*, the membrane in which it is enclosed being too delicate to be detected by the eye.

(4) Feel the smooth covering of cartilage over the ends of the bones; cut it to observe its texture; note how far it extends. What is its thickness, and where is this most marked?

NOTE.—When the tendons that are interposed between the muscle proper and its place of origin or insertion play over hard surfaces, they are usually separated from such surfaces by *bursæ*, or *sacs* containing fluid; or the surfaces are quite covered by a synovial bag forming a double sheath; this sheath may be compared to the pleura which invests the lungs and walls of the thorax.

VIII.—THE SYSTEMS OF THE BODY AND THEIR FUNCTIONS (*contd.*).

(E) THE MUSCULAR SYSTEM.

Observations on Muscle Action; Structure; and Function.

I.—Observation on Muscle Action.

Materials: *Weight; Paper; Pins.*

(*A*) Clasp the front of the right upper arm; draw up the forearm as strongly and as far as possible. Repeat the action, feeling the tendon at the lower end of the muscle.

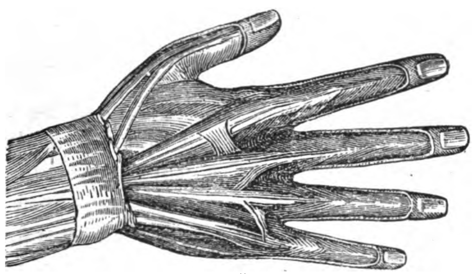

Fig. 37.

(*B*) (1) Examine the back of the hand; bend and extend each finger in turn. Trace out the tendons. Notice the tendon of the little finger and compare it with that of the thumb. Examine the knuckles, and try to make out their structure (*Fig.* 37).

(2) Place a weight in the hand and repeat (1), noticing any change in the conditions of muscles and tendons.

(*C*) (1) Span the biceps muscle by placing the tips of the fingers in the angle of the elbow, and stretching the tip of the thumb as far as possible up the arm towards the shoulder; again bend the arm and note the result. Measure the length of the span in each position and record the difference between the two (*Fig.* 38, *p.* 156).

(2) Clasp the upper side of the right forearm near the elbow. Clench the right hand quickly and forcibly. Repeat this movement rapidly, and note the various changes which occur in appearance and sensation.

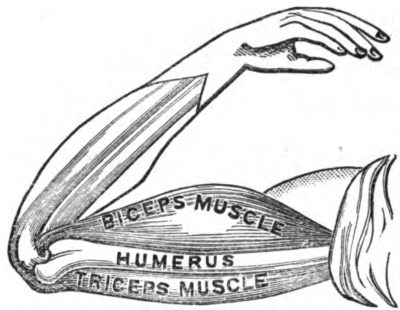

FIG. 38.

(*D*) (1) Observe the thick mass of muscle at the base of the thumb. Pinch the forefinger and thumb strongly together. What changes are seen and felt in this muscle mass?

(2) Press the fingers on one temple; open and then shut the jaw firmly and feel how the temporal muscles act. Compare with the observations made in (1).

(3) Pin a strip of paper lightly round the upper arm. Lift a weight to the shoulder. How does the result throw light upon the changes undergone by muscles in action?

(4) Place the feet near together, then rise on the toes; lower and raise the body thus several times in succession, bending the knees and ankles. Record observations on the action of the muscles involved in these movements.

NOTE.—These demonstrations of muscle action will illustrate the fact that, when contracted, muscles become shorter, thicker, and harder. Note also that several muscles, or groups of muscles, take part in maintaining the erect posture of the body, and in nearly all movements. Many more illustrations can be devised, which afford further corroboration of the facts it is desired to emphasise.

It is useful to find, with the assistance of a good chart, the position of the most important muscles in the body, such as the *biceps* and *triceps*, the *deltoid*, the *gastrocnemius*, the *sartorius*, etc. (*Fig.* 39).

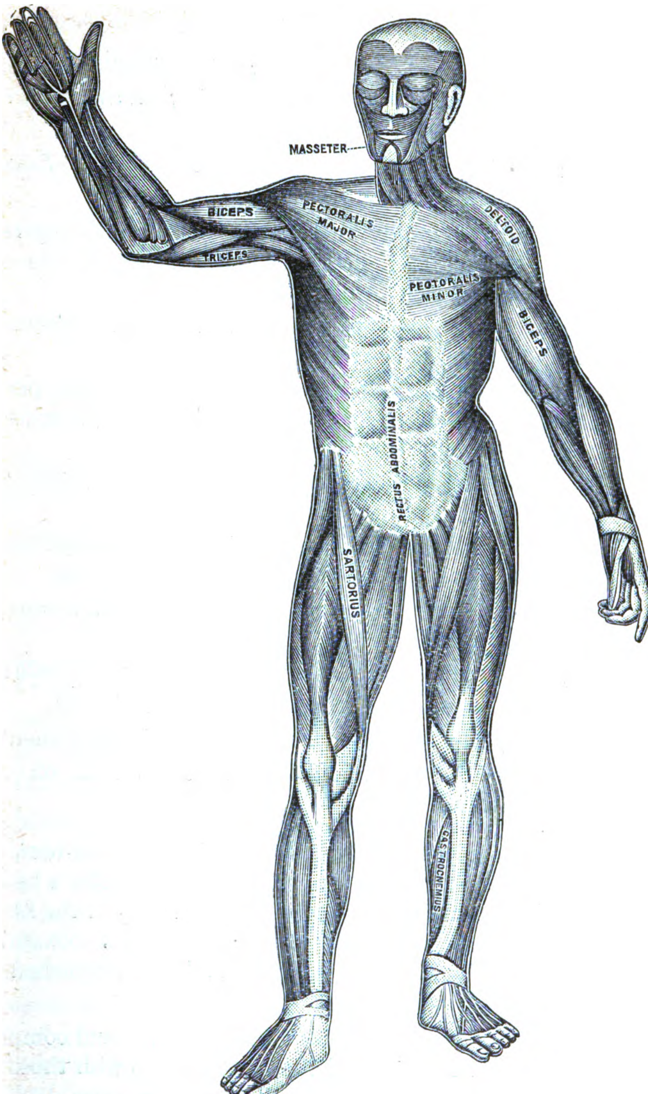
MASSETER
BICEPS
TRICEPS
PECTORALIS MAJOR
DELTOID
PECTORALIS MINOR
BICEPS
RECTUS ABDOMINALIS
SARTORIUS
GASTROCNEMIUS

FIG. 39.

II.—Muscle Structure.

MATERIALS: *Leg of freshly killed rabbit; piece of well-boiled, lean corned-beef; large darning-needles; water; fine red cord; tissue paper.*

APPARATUS: *Dissecting instruments and board; hand-lens; Bunsen burner.*

(*A*) Skin the leg of a freshly killed rabbit and carefully separate one entire muscle from the surrounding tissues, but do not sever it at either end. Observe:—

(1) The thin sheath of connective tissue or *perimysium* in which the muscle is wrapped.

(2) Divide this sheath at one point, and trace the partitions which pass from its inner surface, forming numerous compartments of various sizes.

(3) Note the muscle substance (or fibres) which fills these divisions.

(4) Trace the *perimysium*, or *fascia*, to its termination in a tendon, which is formed of dense, connective tissue.

(5) Identify the belly, or red central part, of a muscle and its tapering ends.

(6) Distinguish the points of attachment of the muscle:—

(*a*) The origin, or less moveable attachment.

(*b*) The insertion, or more moveable attachment.

(7) Move the limb, and observe the results on the exposed muscles.

(*B*) (1) Take a piece of well-boiled, lean corned-beef, in which the fibres run all one way. Press it under a heavy weight; place it on the dissecting board, and pick the fibres apart with large darning or dissecting needles. Examine with a good hand-lens. What is to be distinguished in respect of muscle structure?

(2) Boil the leg of a rabbit for some hours, and compare the subsequent condition of the muscle fibres with those in the corned-beef; observe the similarity of structure.

NOTE.—The *fascia* or *perimysium* of muscle fibres consists of *connective tissue* which is destroyed by prolonged boiling in water. It is this destruction of the sheaths of the muscles which causes that condition in cooked meat described as being "boiled to rags." The perimysial case is broken up, and the muscle fibres are separated one from another.

A rough representation of muscle structure may be made as follows:—Cut a number of pieces of fine, red cord into varying lengths. Wrap each in a sheath of very thin tissue paper, slightly longer than the piece of cord. Form a bundle of these and enclose it in a cover of similar paper, of which one end is long enough to be rolled into a compact rope; this rope will represent a tendon. It is, however, advisable to associate the employment of any such crude illustration with a clear explanation of the soft, semi-fluid condition of muscle-fibres in the living body, in order to avoid the misapprehension so easily formed in the minds of young children.

III.—The Function of Muscles in Movements. (*Adapted from "Woodhull's Home-made Apparatus."*)

MATERIALS: *Pieces of wood or stiff card; small knife; measuring ruler; 3 bands of elastic; small strips of tin; drawing pins; hooks and eyes; needles; thread.*

Make a model to illustrate the combined work of muscles, bones, and joints in the arm. Take three pieces of wood or stiff card:—

(*a*) 10 cms. × 7 cms. × 1 cm. (4 in. × 3 in. × $\frac{1}{4}$ in.).

(*b*) 22 cms. × $2\frac{1}{2}$ cms. × 1 cm. (9 in. × 1 in. × $\frac{1}{4}$ in.).

(*d*) 10 cms. × $2\frac{1}{2}$ cms. × 1 cm. (4 in. × 1 in. × $\frac{1}{4}$ in.).

Make a slightly semi-circular cavity on one side of (*a*) for a distance of 3 cms. ($1\frac{1}{5}$ in.), at a distance of 2 cms. ($\frac{4}{5}$ in.) from the upper edge.

Round off the corners of one end of (*b*) so that the convexity which results will correspond with the concavity in (*a*). Fix one end of a small strip of metal or card (*c*) to the flat surface of (*b*) about the middle of this rounded end, and attach the other end of (*c*) to the flat surface of (*a*) about the middle of the corresponding concavity. A second strip will hold the two pieces (*d*) and (*b*) in contact and will act as a hinge, so permitting

of a little movement. The whole represents the ball and socket joint which connects the shoulder (*a*) with the arm (*b*), though (*d*) will, of course, reproduce very poorly the formation of the fore-arm, with its two bones, the radius and the ulna (*Fig.* 40).

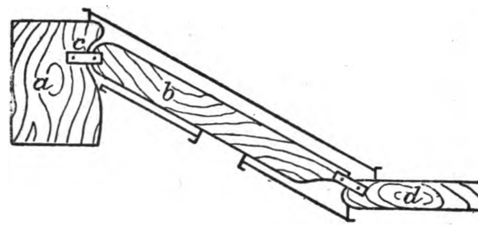

FIG. 40.

To form points of attachment for the biceps and triceps muscles, which will be represented by rubber bands, fix six small hooks or drawing pins to the various pieces of the model, as follows:—Attach one to the upper edge of (*a*) and a second just below the concavity. Fix two more on the under edge of (*b*) 9·75 cms. (4 in.) from each end; they will be 2·5 cms. (1-in.) apart. Fix two more on the upper and under edge of (*d*) respectively, just beyond the place (that is further from the joint) where the hinge is attached. Connect the hooks or pins on the upper surfaces of (*a*) and (*d*) with one elastic band, and link the hook on the lower edge of (*a*) with the hook nearest to it on (*b*), with a second and shorter one; a third band, similar in length, must connect the remaining two hooks.

When all is in place, proceed to move the various parts of the model. For this purpose it will be necessary to detach and reattach the bands. In the first place, adjust the three bands so that (*b*) and (*d*), which roughly represent the arm, hang down straight from (*a*). Readjust them, so that (*d*) is bent upwards at the elbow; and again, so that (*d*) is folded forwards and inwards.

Notice how the muscles work in opposition to each other over the joints; how the joint is fixed; and which muscle (*i.e.*, rubber band) plays the most important part in the various movements.

IV.—The Mechanics of Motion.

The bones, muscles and joints in the body are arranged in such a way as to act as *levers*, by means of which range of movement can be greatly enlarged or power much increased. In man, this system of leverage, as applied to the bones, is usually employed to increase the rapidity and range of movement; though in some actions, such as standing on tip-toe, for example, range of movement is very limited, but, on the other hand, power is gained. The principle of the lever is that of a bar, straight or curved, resting on a fixed point or edge, which is called the *fulcrum*. The forces acting on the lever are :—

(1) The weight or resistance.

(2) The power and reaction of the fulcrum.

Levers are divided into *three* kinds, according to the position of the fulcrum with respect to the points of application of the power and the weight.

When a poker is used to raise coals in a grate it illustrates a lever of the *first* kind, *i.e.*, where the fixed point or fulcrum (some portion of the grate), is between the resistance or weight (the coals) and the power (the hand).

The opening or closing of a door illustrates a lever of the *second* kind or order, *i.e.*, the weight or resistance is between the power (the hand) and the fulcrum (the hinges of the door).

A pair of sugar-tongs illustrates a lever of the *third* kind, *i.e.*, the power or pressure of the hand in this case lies between the fulcrum and the weight (the sugar).

Thus, briefly, the three orders of levers have respectively the fulcrum, the weight, and the power in the middle position. In the human body the joints constitute the fulcra, and the power is applied at the insertion of the muscles close to the joints concerned in the action performed.

(*A*) Perform the following actions which show levers of the *first class*, often described as "levers of stability."

(1) Nod the head to and fro, from back to front and *vice versa*.

(2) Extend the forearm and straighten the elbow joint.

Point out in each case which joint constitutes the fulcrum, what part of the body represents the weight, and which muscles apply the power in these movements.

(*B*) Perform two more actions to illustrate levers of the *second class*, "levers of power," where the weight is between the power and the fulcrum.

(1) Stand on tip-toe.

(2) Hop a few steps.

Trace in each movement, as in (*A*), the relative position and the part of the body, whether joint or muscle, which represents the power, weight, and fulcrum in these illustrations of lever actions.

(*C*) Perform selected movements to illustrate the *third class*, "lever of rapidity," where the power lies between the weight and the fulcrum.

(1) Extend or straighten the leg at the knee joint.

(2) Balance some small object (as a ball, a small book, or a paper-weight) upon the toes, with the foot resting on the floor. Then, using the heel as a fixed point, raise the weight from the floor by means of the toes. Note once again the parts of the body called into action by these movements and the position of weight, fulcrum and power.

NOTE.—In (*A*) (1) the joint which serves as fulcrum is that between the atlas and axis (the first two bones of the spinal column), the head is the weight and the neck muscles are the power.

In (*A*) (2) the elbow joint is the fulcrum, the forearm and hand form the weight, the triceps muscle (which pulls on the projection of the ulna), is the power. Other illustrations of this kind of lever are found in the movements of the *ossa innominata* upon the *femurs* (thigh bones); in the particular arrangements by which the spinal column is balanced on the haunch bones, and the leg upon the foot; or when the ball of the foot is pressed down while working the treadle of a sewing machine.

In (*B*) (1) the ball of the foot as it rests on the ground is the fulcrum, the weight or resistance is that of so much of the body weight as is borne by the ankle, the power is applied by the muscles of the calf, where they are attached to the back of the heel by the *tendo Achillis*.

In (*B*) (2) it must be borne in mind that in the act of hopping the thigh bone of the leg is bent upwards and not used; so, in this case, the fulcrum is at the hip-joint, the position of the weight is between the thigh and the knee, while the power lies in the thick muscle of the front of the thigh, which extends from the haunch bone to the knee-cap.

Examples of this lever are not very easily found in the body, but an illustration is afforded in a rib when depressed in expiration by the *rectus* muscle of the abdomen; the fulcrum is then situated at the point where the rib is articulated with the spine, the power is at the sternum, and the resistance to be overcome, *i.e.*, the weight, is between the two.

In (*C*) (1) the fulcrum is the knee joint, the power is applied by the muscles in front of the thigh, through the ligament of the knee-cap to the *tibia*, the weight is somewhere between the knee and foot.

In (*C*) (2) the fulcrum is at the ankle joint, the weight is that balanced on the toes, the power lies in the flexor muscles of the foot. This lever is very common in the human body; it is employed when the forearm is bent on the upper arm; or when maintaining the erect position of the body, with the centre of gravity within the base of support. It is desirable to bear in mind that, according to circumstances, one part of the body, notably the foot, may represent more than one of these three kinds of lever. If the foot be raised from the ground and the toes tapped on the floor, it illustrates a lever of the first order (the ankle is the fulcrum, the toes the weight, the power is applied by the calf muscle).

The reference to (*B*) (1) describes in detail the employment of the foot as a lever of the second order, and in (*C*) (2) the foot is again used to illustrate a lever of the third order.

V.—Muscular Force.

MATERIALS: *Heavy weight; light ball; large book; a small object; a heavy bag.*

(*A*) Hold a heavy weight, a light ball, a large book, and a small object at successive intervals for a few minutes.

Observe how soon fatigue is felt in each case.

(*B*) Carry a heavy bag for five minutes:—

(1) with the arm bent;

(2) with the arm fully extended by the side.

Again compare the fatigue experienced in each instance.

NOTE.—Muscular force must be continually exerted in (*A*) to counterbalance the constant action of gravity, as the pressure of the hand must be adjusted accurately to ensure equilibrium. If a heavy object be carried with the arm fully extended as in (*B*) (2) it is slung to the shoulder by the *bones* and *tendons*, part of whose functions it is to relieve the muscles of weight, and so to save fatigue; in the case of (*B*) (1), when the arm is bent, the weight falls almost entirely upon the *muscles*, and the muscular effort soon causes fatigue and discomfort.

VI.—To measure Muscular Force.

MATERIALS: *A strong, spring balance;* 14 *to* 28 *grams* (½ *to* 1 *ounce*) *of sugar.*

Hold the spring balance with both hands, and pull on each end with all the strength possessed. Read and record the index. The number of kilograms or pounds registered will show the muscular force exerted, *i.e.*, it will be equal to the pull or weight of the number of pounds registered.

Repeat the pull several times in succession, recording the number of kilograms or pounds marked by the index at each effort. Repeat the test:—

(*a*) Early in the day;
(*b*) Before going to bed;
(*c*) When hungry;
(*d*) Shortly after a meal.

Does the record vary at different times or under different conditions?

Test the statement that "to eat from half to one ounce of sugar increases the muscular power." After what interval of time is this increase perceptible?

NOTE.—The influence of periodicity or rhythm is very strong in respect of muscular vigour. This reaches its highest point between 10 and 12 a.m., which hours are therefore indicated as the best for physical exercise; the curve of muscular vigour rises temporarily after meals and falls to its lowest point between 10 p.m. and 5 a.m.; it is affected by alcohol and tobacco, or other nerve stimulants and narcotics.

VII.—The Muscular Sense.

MATERIALS: *Pencil; sheet of paper; measure.*

(*A*) Repeat "THE NERVOUS SYSTEM," (1), II. (*C*), *page* 95.

(*B*) Draw a line (*a*) ————. Shut the eyes. Draw a similar line (*b*) ————.

Measure the length of (*b*) and compare it with (*a*).

Repeat the experiment several times, and observe what improvement takes place in the muscular sense.

NOTE.—It is through this sense that a young child enters into its principal and earliest relations with its surroundings; concerned as it is with sensations arising from movements either active or passive. The muscular sense is so diffused and variable in the scope and character of its records that it is difficult to define or even to localize accurately. It may give a feeling of resistance when any obstacle is opposed to bodily movements; it may cause sensations of contact, pressure, resistance to effort or consciousness of the position of any part of the body, or of the direction and extent of any movement of any part of the body; indeed, it supplies the basis of our knowledge of the position, or of the movements of all the parts of the body, without the assistance of sight, or touch.

IX.—GENERAL CONSTITUENTS OF THE BODY.

Identification of the Proximate Principles (proteids, carbohydrates, fats, salts, water), present in an animal body. Employment of 'control tests' as evidence.

I.—Tests for the Presence of Proteids (Nitrogenous Substances).

MATERIALS: *Egg albumin solution; concentrated nitric acid; Millon's reagent; ammonium hydrate; starch jelly; grape sugar; water; milk; raw meat; prepared fat;* 1 % *solution cupric sulphate; concentrated solution caustic soda; cochineal.*

APPARATUS: *Test tubes; thermometer; beaker; sand-bath; Bunsen burner; retort stand.*

(*A*) *Solubility.*

(1) Take two test tubes, (*a*) and (*b*). Put 15 c.c. of distilled water in (*a*) and 15 c.c. of alcohol in (*b*). To each add 5 c.c. pure egg albumin and stir briskly. Compare the results. Repeat the experiment, but instead of the egg albumin use a solution of warm gelatine, and compare the results in respect of solubility in each case.

(2) Prepare a dialyser as directed in "CHARACTERISTICS OF LIFE," III. (*B*), *page* 25. Half fill it with egg albumin solution (*see page* 21). Set it aside for twenty-four hours. Remove, with a pipette, 5 c.c. of the water from the vessel in which the dialyser is suspended, and test by the Biuret reaction (*see* (*D*) (3), *page* 169), for the presence of any albumin which may have passed through the membrane used for the experiment. Set aside the test tube for purposes of colour comparison later on.

(3) Half fill a test tube with egg albumin solution; add a few drops of a solution of pepsin and fill up the tube with 0·2 per cent. solution of hydrochloric acid (*see* "THE PREPARATION OF ARTIFICIAL GASTRIC JUICE," *infra*). Place the tube into a vessel of warm water and maintain a temperature of 37·8C. (100°F.) for half an hour, stirring the contents of the tube at intervals with a glass rod. During this time a process of artificial digestion will take place, by which the insoluble, colloidal proteids will be converted into soluble, diffusible peptones.

Refill the dialyser with this solution of peptones. Leave for twenty-four hours as in (2). Again remove 5 c.c. of the water which surrounds the dialyser and test by the Biuret reaction (*D*) (3), *page* 169, for any change in its character. What evidence does the result afford as to the action of the gastric juice during the process of digestion, and its effect upon the relative solubility of proteids and peptones? (*See* "ELEMENTARY STUDY OF THE DIGESTIVE PROCESS," III., and NOTE, *infra*).

(*B*) *Coagulation.*

(1) By heat.

(*a*) Arrange a beaker, three-parts full of cold water, on a retort stand over a Bunsen burner. Take 5 c.c. of undiluted egg albumin in a test tube, and support the tube in the beaker by passing it through the smallest ring of the retort stand, which must be fixed above and just over the centre of the beaker. Introduce a thermometer into the test tube, taking care that the bulb is well covered by the egg albumin solution. Support the thermometer in this position by adjusting a second ring of the retort stand for the purpose, through which the upper part of the thermometer can be passed.

Light the Bunsen burner and gradually heat the water, stirring it continually with the test tube. Note what changes take place in the egg albumin, and at what temperature they occur.

(*b*) Drop some egg albumin on the surface of boiling water; compare results with those obtained in (*a*).

(*c*) Repeat (*a*), but substitute for the egg albumin (1), 5 c.c. of milk and (2), 5 c.c. of juice squeezed from fresh, raw, lean meat. Compare the results obtained in each case with those in (*a*) and note the temperature at which coagulation occurs in each experiment.

NOTE.—To coagulate the albumin in milk by heat, it is necessary to heat the milk several times, allowing it to cool in the intervals.

(2) By acid.

To 5 c.c. of nitric acid in a test tube, add an equal quantity of egg albumin solution, and notice how very rapidly coagulation takes place. The same test for the coagulating power of strong acids upon proteids may be repeated with milk, or with the serum of blood, or with fresh meat juice.

(*C*) *Diffusibility.*

Take two beakers (*a*) and (*b*). Half-fill (*a*) with a strong solution of sugar and water; half-fill (*b*) with pure egg albumin or a warm solution of gelatine. Pour 25 c.c. of distilled water, tinted with cochineal, upon the surface of the substance in each beaker. Observe any evidence of diffusion in both cases after one minute, 30 minutes, and 24 hours.

(*D*) *Colour reactions.*

(1) *The xanthoproteic test.*

(*a*) Take 5 c.c. egg albumin solution in a test tube; add 5 c.c. concentrated nitric acid; a white precipitate will result. Boil the contents of the test tube; they will become yellow during the process. Cool *thoroughly*, and add 5 c.c. ammonium hydrate. The mixture will turn reddish-orange, or almost red. Watch these changes as they take place, and the order in which they occur, as the test will be constantly employed for the detection of proteids in different organic substances.

NOTE.—This "colour reaction" (or chemical change, produced by bringing at least two elements or compounds together, whereby one or more new bodies are formed) depends, in this instance, on the presence of what is technically described as an "aromatic radicle" in the proteid molecule.

(*b*) Take three test tubes, (1), (2), and (3). Put into

(1) Some dilute starch jelly.
(2) Some grape sugar.
(3) Some prepared fat.

Treat each respectively as in (*a*), and record the observations made.

(2) *Millon's test.*

(*a*) Take 5 c.c. egg albumin solution, add a drop of Millon's reagent; a white precipitate will fall. Boil the solution, and note the change in colour of the precipitate to a brick-red.

(*b*) Repeat (*D*) (1), (*b*), using Millon's test instead of the xanthoproteic.

NOTE.—Millon's reagent consists of mercury dissolved in twice its weight of nitric acid (sp. gr. 1·42), the solution being diluted with three times its volume of water. A *reagent* is any substance employed to bring about a chemical reaction or to change another element or compound, with a view either of detecting its presence in, or of effecting its separation from, other substances. The colour reaction depends on the presence of an aromatic molecule, as in (*D*) (1), (*a*).

(3) *Rose's, Pióŧrowski's or the Copper Sulphate Test, known also as the "Biuret" reaction.*

(*a*) Take 5 c.c. egg albumin solution in a test tube. Add first two to three drops of a 1% solution of cupric sulphate, and then 10 c.c. of a concentrated solution of caustic soda. A violet colour should develop, but it may be concealed if too much copper solution be used.

(*b*) Repeat (*a*), but substitute 5 c.c. of the digested egg albumin solution prepared in (*A*) (3), *i.e.*, a solution containing peptones, for the proteid solution previously employed. A rose-red colour will develop instead of the clear violet tint.

(*c*) Repeat (*D*) (1), (*b*), but substitute this test for the xanthoproteic.

NOTE.—This test for the presence of proteids is generally known as the "Biuret reaction," not because biuret is present in proteids, but because the nitrogenous substance, *Biuret* (which is formed by heating solid urea to 160°C. (320°F.)), gives the same colour reaction to the test as that given by peptones, possibly because they possess a common radicle, probably C, O, N, H. Peptones are classified as the lowest members of the proteid group.

If this test is to be reliable, two precautions are necessary :—

(1) The solution of proteid must be alkaline. It should, therefore, be tested with neutral litmus paper, and, if necessary a little sodium hydrate must be added.

(2) Great discretion must be used in the addition of the dilute cupric sulphate solution; any excess will give an apparent test in the absence of proteids.

Proteids are the most important among the substances which occur in animal and vegetable organisms, from the fact that, in their absence, none of the phenomena of life can take place. Thus they derive their name of proteids, or substances having the *pre-eminence*, because they are of the first importance to life. They are highly complex compounds of nitrogen, carbon, hydrogen, and oxygen, with a trace of sulphur, but definite knowledge of their chemical composition is still incomplete; this fact, however, is assured, that proteids occur in a solid, viscous condition or in a solution in nearly all the solids and liquids of the body.

The group of proteids consists of several members (albumins, globulins, vitellins, nucleo-proteids, etc.), which are distinguished by different chemical and physical properties, but they are all united by a close, genetic relationship. They possess, also, certain characteristics in common, the most important of which are here enumerated.

(1) *Solubility.* All proteids are insoluble in alcohol and ether, but some (*albumins*) are soluble in water; others (*globulins*) which are insoluble in water are soluble in weak saline solutions. All are soluble in the gastric and pancreatic juices, being converted into a hydrated variety of proteid called peptone—though they pass first through an intermediate form in which they are described as proteoses or albumoses.

(2) *Coagulation,* (*a*) by heat or acids. Most proteids coagulate with heat, though the temperatures at which they are rendered thus insoluble vary from 56°C. (132°F.) to 75°C. (167°F.), in different members of the group. (*b*) By ferments. For example, the proteids in milk are coagulated by the ferment in rennet, or those in blood when shed are coagulated by the fibrin ferment.

(3) *Diffusibility.* Proteids belong to the class of colloid substances which diffuse with difficulty and very slowly. They pass with much difficulty, if at all, through animal membranes; vegetable parchment is therefore largely used in the construction of the dialysers employed for experimental purposes. It is important to distinguish between *diffusion* and *dialysis.* The latter term applies where *two* solutions are separated by a membrane, through which certain only of their constituents make their way; whereas, in the

former, a solution is brought into immediate contact with the surface of another solution or substance, so that the composition of the mixture gradually becomes uniform. The time occupied in this process of diffusion may be short, as when water is poured upon sugar, or long, as in the case where water is poured over a mass of gelatine or albumin.

(4) *Colour Reactions.* Several chemical tests which are characteristic of proteids are constantly employed to indicate their presence in animal or vegetable substances, but Professor Vervorn, (of the University of Jena), points out that these tests are but empirical, as it is practically unknown what chemical transformation is undergone by the proteid molecules. It is always advisable to employ more than one test where it is desired to confirm the presence of proteid matter.

It has been already stated that proteids are altered in character by the gastric juice, being changed first into *proteoses* and then into *peptones*. In this latter form they lose their colloid properties, become readily diffusible through animal membranes, and are no longer coagulable. Proteids are thus prepared for absorption into the blood, for which purpose solubility and diffusibility are indispensable qualities.

Professor Halliburton emphasises the importance of making a careful distinction between the words *coagulation* and *precipitation* in connection with the properties of different members of the proteid group. The term *coagulation* is used when an insoluble proteid is formed from a soluble one; this may occur (1) when a proteid is heated; (2) under the influence of ferments; (3) when an insoluble precipitate is produced by the addition of such reagents as nitric acid or tannin. There are, however, other precipitants of proteids in which the precipitate formed is readily soluble in suitable reagents, (especially saline solutions), and the proteid continues to show its typical reactions. Such precipitation is not coagulation.

Globulins are soluble in saline solutions, albumins in distilled water; thus, serum globulin is precipitated by half saturation with ammonium sulphate. In fact, globulins are precipitated by certain salts (such as sodium chloride and magnesium sulphate) which do not precipitate the albumins. The precipitation produced by alcohol is peculiar in that, after a time, it becomes a coagulation.

In order to show that proteids do actually contain nitrogen, perform the following experiments.

Mix, in a porcelain dish, with a knife or glass rod, one part of dried egg albumin with two parts of powdered soda-lime, and add just sufficient distilled water to make the whole into a paste. Roll this paste with the fingers into small balls about the size of large pills, and place two or three of them in a dry, warm test tube. Hold it in a horizontal position with a test tube holder, and direct the mouth away from the face. Heat the tube by waving gently to and fro over a Bunsen burner. As the process of heating proceeds, hold a piece of moist, red litmus paper in the vapours given off until a change of colour is observed. The fact that it will become blue (an indication of the presence of an alkali), and that the vapour will diffuse the familiar, pungent odour of ammonia, prove that egg albumin contains ammonia, and is in consequence a nitrogenous substance, for ammonia gas consists of one measure of nitrogen chemically combined with three measures of hydrogen, whereas soda-lime contains absolutely no nitrogen. The inference therefore is obvious that, since ammonia gas cannot be formed in the absence of nitrogen, the source from which it proceeds must be the egg albumin. The detection of nitrogen in an organic compound is always difficult, even with experience, skill, and every advantage of apparatus. To ensure success in this apparently simple experiment the following precautions must therefore receive careful attention, or disappointment will follow.

(1) The test tube must be perfectly dry and preferably hot.

(2) The porcelain dish must also be dry and scrupulously clean.

(3) The mixture should be made into small balls, arranged to allow of sufficient intervening space so that the gas can escape freely as it is generated. If the powder were deposited at the bottom of the test tube and this was held vertically, the mixture would cake on the application of heat, and the gas would force its way through the place of least resistance, *viz.*, that side of the test tube most softened by the Bunsen flame.

(4) Soda-lime has a great affinity for water, consequently it must be kept in a well-stoppered bottle; if for any reason it becomes damp, place the compound in a flat dish and expose it to a moderate temperature in the air-oven until all moisture has evaporated. Then return it to the bottle while still hot.

It is more satisfactory and convenient for elementary students to test for the presence of the proximate principles, rather than for the elements in chemical combination of which they are composed. This test is not therefore suggested for frequent employment, though successful experiments with various food stuffs can be performed by its aid if sufficient care be exercised in attention to details.

II.—Test for the presence of Carbohydrates (Starch, Sugars).

MATERIALS: *Grapes; starch jelly; grape sugar; prepared fat; egg albumin solution; Fehling's solution; iodine solution; filter paper; water.*

APPARATUS: *Thistle funnel; test tubes; beaker; c.c. measure; Bunsen burner.*

(*A*) *Tests for the presence of Starch.*

(1) Place a little of the starch jelly, prepared as directed (*page* 186), in a test tube and add a drop of iodine; observe the effect carefully, and record the result.

(2) Add a similar quantity of the starch jelly to a large glassful of water; stir in a few drops of iodine and compare with (1).

(3) Add a few drops of iodine to a small quantity of water; again note and record the result.

(4) Add a few drops of iodine to a small quantity of raw starch. Compare the result with those obtained in (1) and (2).

(5) Take three test tubes, (*a*), (*b*), and (*c*). Place in

(*a*) A small amount of grape sugar, prepared as directed (*page* 174).

(*b*) A little egg albumin solution.

(*c*) Some fat, prepared as directed (*page* 186).

Add a few drops of iodine to each tube and compare the results with (1) and (2).

NOTE.—Upon the addition of iodine solution to an opalescent starch solution a blue colour results, which disappears on heating and returns on cooling—that is to say, if all the iodine (which

is volatile) has not been driven off. Excessive heat must, therefore, be avoided or the blue compound, formed by starch with iodine, will be decomposed. No explanation can yet be offered of the cause of the formation of this characteristic blue colour when iodine comes in contact with starch.

By observing the precaution just mentioned, the pupil is in a position, after carrying out this group of experiments, to determine, by the aid of the iodine test, whether a substance contains much starch, little starch, or no starch.

(*B*) *Test for the presence of Grape Sugar* (*Dextrose*).

(1) Crush two or three grapes in a basin or a mortar with a little water. Filter the liquid. Boil 15 c.c. of Fehling's solution in a test tube; if no change of colour takes place and it remains clear, the solution is in good condition; if it becomes yellow on heating it is not fit for use, and a fresh solution must be procured. (The reason for this is that an isomeride is formed from the tartaric acid, which reduces the cupric to a cuprous oxide.) Add 1 c.c. of the filtered grape juice to the Fehling's solution and boil. The brick-red precipitate indicates the presence of grape sugar.

(2) Take three test tubes, (*a*), (*b*), and (*c*). Place in

(*a*) Some egg albumin solution.

(*b*) Some dilute starch jelly.

(*c*) Some prepared fat.

Add Fehling's solution to each, in the proportions given in (1), and boil, comparing the results with those obtained in the control test experiment.

NOTE.—Fehling's solution is a solution of alkaline potassic-tartrate of copper. The sugar acts as a reducing agent, and changes the cupric to a cuprous salt. This is characteristic of *dextrose*; other sugars (*maltose* and *lactose*) also, though in a lesser degree, reduce metallic salts. The brick-red precipitate is cuprous oxide. *Dextrose* (grape sugar or glucose) is found in many fruits and is an important food-stuff. In the healthy animal body it occurs in minute traces in blood and muscle. It is soluble in water and in alcohol, and is only slightly sweet. Pupils must be trained, without excep-

tion, to test the condition of Fehling's solution by boiling, before employing it as a test, for the reasons given in (1). The solution should be preserved in small, well-stoppered bottles, kept full, and in the dark.

III.—To Detect the Presence of Fat.

MATERIALS: *Benzine; 1% solution osmic acid; lard or prepared fat.*

APPARATUS: *Test tubes; thistle funnel; glass slide; tissue, filter, and writing paper; glass rod; beaker.*

(*A*) Add 2 c.c. benzine (or ether) to a little lard or prepared fat in a test tube. Shake very thoroughly, observing any changes which occur. Filter through filter paper, and allow a drop of the filtrate to evaporate on a piece of clean glass or tissue paper.

(*B*) Melt a little lard in a test tube; drop a very small quantity from the end of a glass rod on to a glass slide or slip of writing paper and smear it about gently. Compare the appearance when dry of (*A*) and (*B*).

(*C*) Place a little fat in a test tube. Add a few drops of 1% solution of osmic acid. The fat turns black.

NOTE.—For advanced work *ether* (*i.e.*, ethyl ether) is essential to success, but for elementary class work it can be generally replaced by petroleum ether, (variously described as benzine or naphtha). This should be a low boiling spirit between 35° and 50°C. (95° to 122°F.), consequently great precautions are necessary to avoid accidents in a laboratory or school kitchen where gas is being freely burned.

IV.—To Detect the Presence of Water.

MATERIALS: *Fresh raw meat; fat; starch; sugar; 2 eggs; filter paper.*

APPARATUS: *Small flask; test tubes; glass tube; glass rod; cork with 1 hole; small porcelain dish; balance; air-oven; Bunsen burner.*

(*A*) Place a piece of fresh meat in a small flask or large test tube. Fit a delivery tube into the cork; close the mouth of the flask or test tube and connect the delivery tube with

a dry, empty test tube, enclosed in a pad of wet filter paper. Heat the flask gently. After a few minutes examine the interior of the test tube for evidences of moisture. Repeat this experiment with portions of fat, starch and sugar.

(*B*) Take a small porcelain dish and a glass rod that will balance across the top of the dish without slipping wholly in, or falling over. Weigh the two and note the combined weight. Add 50 c.c. pure egg albumin. Take the combined weights of dish, rod and egg albumin with great accuracy. Place the dish and its contents in the air-oven and regulate the heat to a temperature of from 100° to 110°C. (212° to 230°F.). Maintain this temperature for several hours, stirring the white of egg about every half hour, until there is no trace of moisture on the inner surface of the oven. When the whole apparatus is apparently dry, allow the dish to cool and then weigh. Note the weight, and compare with that previously recorded.

Heat the dish and its contents to the temperature of boiling water for one hour more, and weigh again. If the weighings agree, all the water has been driven off.

NOTE.—The egg albumin must be stirred occasionally, otherwise the surface coagulation will prevent the water in the lower part of the dish from escaping as steam. If milk be subjected to the same treatment, the same precaution must be observed, and for a similar reason.

V.—Control Tests to employ to detect the presence of Salts.

MATERIALS: *Natural chalk or powdered lime; table salt; metallic potassium; metallic sodium; potassium nitrate; 2 crystals magnesium sulphate; sodium or ammonium phosphate; hydrochloric acid; nitric acid; barium chloride solution; silver nitrate solution; ammonium molybdate solution; distilled water; piece of dark-blue glass.*

APPARATUS: *Pestle and mortar; platinum wire; test tubes; Bunsen burner.*

(*A*) *Calcium.* Grind a small piece of *natural* chalk to a fine powder, or take a little powdered lime.

Moisten the end of a clean platinum wire with dilute hydrochloric acid, and dip it in one of the above powders. Hold the wire by the glass rod or handle to which it is fastened, and gently bring it in contact with the outer edge of a Bunsen flame or a spirit lamp. The *yellowish-red* colour, deepening to brick-red, which appears in the flame, is characteristic of the metal calcium, the principal constituent of chalk and lime.

(*B*) *Chlorides.* Dissolve a few grains of table salt in a test tube containing about 10 c.c. of distilled water. Add one or two drops of silver nitrate solution and note the curdy, white precipitate. Gently heat the test tube over a Bunsen flame, and observe the changes which take place in the precipitate as the temperature is raised, and again when the liquid subsequently cools.

NOTE.—This behaviour on heating is one means of distinguishing silver chloride from other white precipitates. To complete the test, the clear liquid may be poured off and 10 c.c. of liquor ammonia added. The solid precipitate will then dissolve when the tube is gently shaken.

(*C*) *Potassium.* Clean a platinum wire by holding it in the outer edge of a Bunsen flame; then rub it along the surface of a small piece of metallic potassium and again hold it in the flame. Observe the characteristic *lilac* tint.

Look at the flame through a small piece of thick, dark-blue glass, and see the crimson colour assumed. Repeat the experiment, moistening the wire as in the test for calcium, and using saltpetre (potassium nitrate).

(*D*) *Sodium.* Repeat the procedure as in the test for potassium, substituting pure metallic sodium. The *intense yellow* colour is due to sodium. Observe the same flame reaction in compounds of sodium; moisten the platinum wire in distilled water, dip it in some common salt, and hold it in the outer edge of the flame.

(*E*) *Sulphates.* Pour 20 c.c. of distilled water into a test tube; add one or two crystals of magnesium sulphate (Epsom salts) and then add 20 c.c. dilute hydrochloric acid and 20 c.c. barium chloride solution. The *white cloud* produced in the liquid is due to the formation of insoluble barium sulphate.

NOTE.—It is well to recall the fact that barium chloride solution never causes a turbidity in a liquid acidified with hydrochloric acid unless a sulphate be present.

(*F*) *Phosphates.* Dissolve a very small quantity of sodium or ammonium phosphate in distilled water. Place the solution in a test tube (*a*) and add a few drops of strong nitric acid. Add *four or five* drops of this solution of phosphate to a small quantity of ammonium molybdate solution in a second test tube (*b*), and gently warm (*b*) over a Bunsen flame or spirit lamp. As the temperature of the solution rises a *cloudy film* appears in the liquid, and gradually a *canary-coloured* precipitate forms, which clings to the sides of the test tube. This substance invariably forms whenever a phosphate is mixed with ammonium molybdate in the presence of nitric acid.

NOTE.—Great care is required to carry out this delicate test. The ammonium molybdate solution must always be in excess, and must never be heated to boiling point; a very small quantity only of the phosphate solution must be used, but a few more drops may be added if, after heating, no yellowish cloud appears.

VI.—To Detect the Presence of Certain Mineral Matters.

MATERIALS: *Pieces of natural chalk, marble, burnt bone, crushed egg shell; hydrochloric acid.*

APPARATUS: *Test tubes.*

Take four clean test tubes, (*a*), (*b*), (*c*), (*d*). Place in

(*a*) A piece of natural chalk.
(*b*) A small piece of marble.
(*c*) A fragment of burnt bone.
(*d*) Some crushed egg shell.

Pour a small quantity of hydrochloric acid into each tube and carefully observe and compare the result in each case.

NOTE.—To secure vigorous effervescence in the case of the egg shell, it is advisable to boil the acid, in order that the pieces of shell shall be stirred about in the process of ebullition, and thus expose a larger surface to the acid. The tube must be held

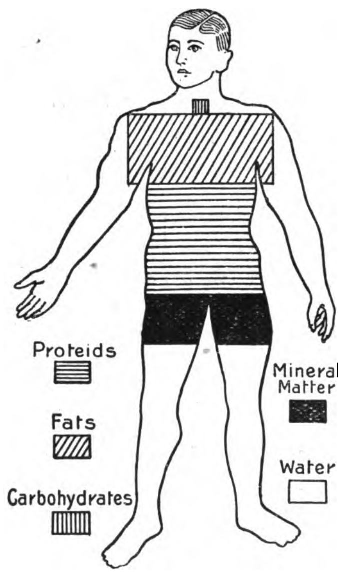

FIG. 41.

in a slanting position, with the mouth *away* from the manipulator or his companion's; great caution being exercised where previous experience is small in connection with the handling of acids and their exposure to heat.

Very few of the large number of chemical elements of which the body is built up occur in the free state. With rare exceptions they are found combined in what are called compounds, more generally described in physiology as the proximate principles of the body. These are divided into two groups, the *inorganic* and the *organic*, of which the latter are by far the more numerous (*Fig.* 41).

Other specimens besides water and the salts, for the presence of which tests are given above, can be supplied to illustrate *inorganic proximate principles* (complex compounds of elements) of which the human body is chemically composed. These can be examined by the pupils as to their general characters and properties. For example: among typical inorganic constituents of the body are water, acids, (*e.g.*, hydrochloric in the gastric juice), alkalies (*e.g.*, ammonia in urine), and salts (*e.g.*, calcium phosphate in bone, sodium chloride in blood, etc.).

The *organic proximate principles* are usually grouped as :—

NITROGENOUS ..	*Proteids* .. *e.g.*, Albumin (from muscle).
	Albuminoids, *e.g.*, Gelatin (from bone).
	Simpler Nitrogenous bodies, *e.g.*, Urea (from urine).
NON-NITROGENOUS	*Carbohydrates*, *e.g.*, Starch.
	Dextrose (grape sugar)
	Fats .. .. *e.g.*, Olein (olive oil).
	Palmitin (lard).
	Stearin (suet).
	Simpler Organic bodies, *e.g.*, Lactic acid.

Professor Leonard Hill suggests showing the proportions of the chief ingredients of the body of a man weighing 150 lbs. in the following way :—

Place 91 lbs. of water in a large glass vessel.

Arrange in jars of suitable size, 18 lbs. dried white of egg and a little less than 9 lbs. of gelatine, which represent the proportion of proteids in the body :—

21 lbs. of fat.

3 oz. of sugar and glycogen.

$8\frac{1}{2}$ lbs. phosphate of lime.

1 lb. carbonate of lime.

6 oz. phosphate of magnesia.

4 oz. fluoride of lime.

Similar amounts of chlorides of sodium and potassium and 4 iron tacks. (*See* "A MANUAL OF PHYSIOLOGY," Chap. VIII.)

X.—ELEMENTARY STUDY OF PROXIMATE PRINCIPLES IN THE BODY.

Typical illustrations. Examination of proximate principles in blood and muscle.

I.—In Blood.

MATERIALS: *Fresh blood; serum and fibrin, prepared as directed (page* 120)*; benzine; Millon's reagent; water; iodine; Fehling's solution; silver nitrate; strong nitric acid; ammonium molybdate; hydrochloric acid; barium chloride; muslin bag; filter paper.*

APPARATUS: *Test tubes; thistle funnel; flat glass dish; balance; air-oven; Bunsen burner.*

(*A*) *Proteid.*

(1) Dilute a drop of blood serum with water. Add a few drops of Millon's reagent and boil. Note the *red* precipitate, which affords evidence of the presence of proteid matter when this test is employed. (*See* "GENERAL CONSTITUENTS OF THE BODY," I. (*D*) (2), *page* 168.)

(2) Wash some fibrin in a muslin bag. Transfer a small quantity from the bag to a test tube, and test it for the presence of proteid by either the xanthoproteic or Millon's tests (*page* 168).

(3) *Globulin* (Kauder's method). Take 10 c.c. of blood serum in a test tube; add to it 10 c.c. of a saturated solution of ammonium sulphate. Shake very vigorously for some minutes, set the test tube aside until the precipitate falls; this consists of globulin.

NOTE.—Globulins, unlike albumins, are insoluble in water; they are soluble in 5 to 10% solutions of sodium chloride, but insoluble in saturated solutions of sodium chloride, magnesium sulphate, or ammonium sulphate (*page* 170).

(*B*) *Carbohydrates.* Take two test tubes, (*a*) and (*b*). Place in each a small quantity of blood serum, previously diluted, boiled and filtered.

Test (*a*) with iodine, (*b*) with Fehling's solution, and record any evidence of the presence of starch or sugar (*dextrose*) (*pp.* 173-4).

NOTE.—The precipitate of red cuprous oxide, which forms when the test for sugar is employed, shows that a small amount of dextrose is present in blood serum.

(*C*) *Fats.* Add a few drops of benzine to some blood serum in a test tube. Shake vigorously, and continue the usual method of testing for the presence of fat (*page* 175).

(*D*) *Salts.* Dilute some blood serum with distilled water, boil the solution and then filter it. Divide the filtrate into four test tubes, (*a*), (*b*), (*c*), (*d*). Add to:—

(*a*) Five drops of silver nitrate and five drops of strong nitric acid.

The curdy precipitate proves the presence of chlorides (*page* 177).

(*b*) A few drops of strong nitric acid and ammonium molybdate, then boil.

The yellow precipitate proves the presence of phosphates (*page* 178).

(*c*) A few drops of hydrochloric acid.

The bubbles set free indicate the presence of carbonates. ("THE CIRCULATORY SYSTEM," IV. (*c*) (4), *page* 124).

(*d*) A few drops of barium chloride and a similar quantity of nitric acid.

The white precipitate proves the presence of sulphates (*page* 178).

(*E*) *Water.* Take a flat glass dish. Weigh, and note the weight. Add 200 c.c. of fresh blood. Weigh again, and record the weight. Place the dish in the air-oven, supporting it some distance from the bottom of the oven. Keep at a temperature from 100° C. (212° F.) to 110° C. (230° F.), for four or five hours. Cool thoroughly before opening the oven; then weigh the dish and its contents. Return to the oven for one hour, under conditions similar to above.

If the weight, after cooling the second time, is the same as the previous record, the experiment is complete. If any further diminution be registered, the process must be repeated until the weights are the same when registered at two consecutive weighings. The difference between the first weight and the final weight is due to the evaporation of the contained water, and shows the proportion of water contained in the blood (*page* 124).

II.—In Muscle.

MATERIALS: *Raw, lean meat; clean, dry sand; egg albumin solution; Fehling's solution; benzine or ether; spirits of wine or alcohol; iodine; ammonium chloride; ammonium hydrate; cupric sulphate; caustic soda solution; nitric acid; lime water; distilled water; filter paper; platinum wire.*

APPARATUS: *Thistle funnel; test tubes; glass tubing; glass rod; porcelain dish; tissue or unglazed paper; air-oven; knife; pestle and mortar; cork, with one hole; balance; Bunsen burner.*

(*A*) *Proteids.*

(1) Mince a small piece of raw, lean meat and grind it in a mortar with clean, dry sand. Transfer the mass to a porcelain basin, cover with cold water, and allow the extraction of the meat juices to proceed for at least half-an-hour, stirring the mixture from time to time with a glass rod. Filter the liquid and divide it into three portions, (*a*), (*b*), and (*c*). Set the last aside for use in (*B*) (*below*).

Test (*a*) for the presence of proteids by the xanthoproteic test (*page* 168). Add an equal quantity of a saturated solution of ammonium chloride to (*b*); shake vigorously for some minutes; filter, and test for proteid by the Biuret reaction (*page* 169).

NOTE.—The ammonium chloride dissolves the *myosin* (the form in which proteid is present) in muscle, and permits the detection of its presence by this test.

(2) *Albumin.* Place some thin strips of fresh, raw, lean meat in a clean porcelain dish and soak them in warm, distilled water for a full half-hour, stirring *very* gently from time to time. Carefully filter the liquid, which should be almost colourless. Divide the filtrate into three test tubes, (*a*), (*b*), and (*c*), and compare the results of the following tests with those observed in egg albumin solution when exposed to similar treatment. ("GENERAL CONSTITUENTS OF THE BODY," I. (*B*) (1), (2), *page* 167.) Treat thus:—

Expose (*a*) to gentle heat.

Add to (*b*) a few drops of strong nitric acid.

Add a few drops of spirits of wine or of alcohol to (*c*).

(*B*) *Carbohydrates.*

(1) Add a few drops of hydrochloric acid to the contents of the test tube (*c*), reserved from (*A*). This will coagulate the proteid present in the serum. Then neutralise with a solution of caustic potash, which must be added with great caution from a pipette, the effect of each drop being checked by the use of litmus paper.

When the contents of the tube are neutral, use Fehling's solution as previously directed (*page* 174), for the presence of sugar. The result indicates the presence of *glycogen*, the animal starch found in liver, muscle, and white blood corpuscles.

(2) Prove the presence of carbon as follows:—Take a small quantity of raw, minced meat. Heat in the air-oven until completely dried up and brittle. Rub it to a very fine powder, and mix with 20 times its weight of finely-divided copper oxide. Place in a dry test tube, and introduce a well-fitting cork which carries a piece of bent-glass tubing, the free end of which should dip well below the surface of some lime-water contained in another test tube. *Gently* heat the mixture, and continue the process until evidence is afforded of the giving-off of carbon dioxide gas. ("AIR," IV. (*A*), *page* 53.)

CAUTION.—Be careful to remove the lime-water before ceasing to heat the mixture, in order to prevent "back suction."

NOTE.—When any organic compound is heated with copper oxide, the carbon contained in the former unites with the oxygen in the latter, and carbon dioxide gas is generated; this latter, conducted into lime-water, gives the characteristic reaction. The metallic copper deprived of its oxygen by the carbon will coat the inner surface of the tube. It can be easily *brushed* out if the tube is kept dry.

(*C*) *Fats.* Pound a little fresh meat, and shake it thoroughly and vigorously in a test tube with benzine or ether. Filter off the liquid, and allow a drop of the filtrate to fall on tissue or unglazed paper. Observe any indication of the presence of fat (*page* 175).

(*D*) *Salts.* Take a strip of raw, lean meat, and dry it very slowly in the air oven. Twist a piece of platinum wire, fixed to a glass rod, round the dried meat. Hold the meat in the outer colourless flame of a Bunsen burner or spirit lamp; closely watch the flame, a bright-yellow flame proves the presence of sodium salts (*page* 177).

NOTE.—There is no method at once simple and reliable by which to demonstrate the presence of chlorides or potassium salts *in meat.* To reduce organic substances to ash involves great care and trouble; while to test the filtrate of soaked raw meat for chlorides with silver nitrate cannot, for various good reasons, be recommended.

(*E*) *Water.* Weigh a small dish and place in it small pieces of lean beef; then weigh the two together. Dry the meat in the air oven for about three hours at a temperature rather above boiling point. Allow it to cool, and weigh again.

Observe the large percentage of water in lean meat, as shown by the difference in weight (*pp.* 182-3).

XI.—ELEMENTARY STUDY OF THE PROCESS OF METABOLISM.

PART I.—THE DIGESTIVE PROCESS.

Salivary digestion; assisted by cooking. Influence of temperature on salivary digestion. Action of gastric juice. Action of intestinal juices.

THE PREPARATION OF ARTIFICIAL GASTRIC JUICE.—*Pepsin*, 1 *gram; Hydrochloric acid*, 4 *c.c.; Water*, 100 *c.c.*

The essential constituents of gastric juice are hydrochloric acid, and the ferments, *pepsin* and *rennin*. It is generally accepted that the action of rennin is confined to the curdling of milk, so that the above fairly represents the composition of normal gastric juice.

THE PREPARATION OF ARTIFICIAL PANCREATIC JUICE.—*Pancreatin*, 1 *gram; Sodium carbonate*, 3 *grams.; Water*, 300 *c.c.*

TO PREPARE EGG ALBUMIN SOLUTION.—Collect the white of an egg in a c.c. measure. Add 50 times its volume of water, boiled and cooled, or distilled. Shake well, and filter through filter paper (*page* 21).

TO PREPARE STARCH JELLY.—Prepare some starch jelly by stirring a very small quantity of starch into cold water; dilute, and raise the temperature to boiling point over a Bunsen flame. The starch will dissolve and form an opalescent solution, turn this into a small basin to cool; it will then gelatinize and be ready for use.

TO PREPARE FAT (similar to the adipose tissue of the body).—Enclose about 20 grams of beef suet in a small muslin bag, secure firmly, and place in a bowl of boiling water. As soon as it is melted, remove and squeeze out the fat through the muslin into a jar for use; the residue left in the bag is merely connective tissue.

I.—The Digestive Action of Saliva.

MATERIALS: *Saliva; starch; a marble; paraffin gum; ice; filter paper; litmus paper; piece of fresh bread; well-toasted crust of bread; caustic soda solution; 2% hydrochloric acid; Fehling's solution; iodine; water.*

APPARATUS: *Test tubes; glass rod; c.c. measure; beaker; enamelled iron mug; thermometer; Bunsen burner; sand-bath; retort-stand.*

(*A*) Collect some saliva in a large test tube, and dilute it with five volumes of water; filter and use the filtrate as directed in the following experiments:

(1) Test with damp litmus paper; the mixture should be slightly alkaline.

(2) Test with iodine; no starch is present.

(3) Prepare some very weak starch solution by rubbing up 1 gram of starch with cold water, then make up the solution to 200 c.c. Measure off 10 c.c. of the solution in a test tube. Boil the remainder for some minutes.

(4) Half fill six test tubes with saliva solution and label them (*a*), (*b*), (*c*), (*d*), (*e*), (*f*).

(5) Make a water-bath by filling an enamelled iron mug with warm water to a depth of 8 to 10 cms. (3 or 4 in.). Stand it on a sand-bath over a very small Bunsen flame, and support a thermometer in the water (by suspending it with fine wire from the ring of a retort stand), so that the bulb does not touch the bottom. The temperature must not exceed 37·8° C. (100° F.).

(6) Then proceed as follows:—Add to

(*a*) A few drops of the raw starch solution.
(*b*) A few drops of boiled starch solution.
(*c*) A few drops of boiled starch solution *plus* a few drops of 2% hydrochloric acid solution.
(*d*) and (*e*) A few drops of boiled starch solution.
(*f*) A few drops of boiled starch solution, but *boil* the saliva solution before making this addition.

Set (*a*), (*b*), (*c*), and (*f*) in the water-bath for ten minutes, but place (*d*) and (*e*) in a beaker of ice-water. After ten minutes, transfer (*d*) from the ice-water to the warm-water bath for a quarter of an hour.

Divide the contents of each of the six test tubes into two portions, labelling them (a^1), (a^2), respectively, throughout the series.

Test all the specimens marked (a^1) with iodine for the presence of *starch*, and all the specimens marked (a^2) with Fehling's solution for *dextrose*. Do the results correspond with the following statements?

(1) That the *ptyalin* (the active ferment in the saliva), of which the function is to convert insoluble starch into soluble sugar, acts with difficulty if at all upon raw starch;

(2) That it readily fulfils this function when the cellulose envelopes, in which starch grains are enclosed, have been softened or burst by the influence of moist heat;

(3) That it cannot act in an acid medium, but is most active in a neutral or faintly alkaline medium;

(4) That its action is arrested or suspended at a low temperature, but is most pronounced at about the normal temperature of the body;

(5) That it is destroyed by boiling.

(*B*) Make two dialysers as directed in "CHARACTERISTICS OF LIFE," III. (*B*), *page* 25. Place in:—

(1) Some warm, weak starch solution, and suspend in water, kept at a temperature of 37·8° C. (100° F.).

(2) A mixture of saliva and boiled starch, as in (*A*) (6) (*b*). Keep under conditions similar to (1). Examine after two hours for evidence of diffusibility by testing a few drops of the water in each beaker with iodine for the presence of starch, or with Fehling's solution for dextrose.

(*C*) Chew slowly and very thoroughly:—

(1) A piece of crumb of fresh bread.

(2) A piece of well-toasted crust of bread.

Record observations on the effects of salivary action on the flavour in each case.

It will be noticed that in (2) the high temperature to which the crust of the loaf has been subjected, first in baking and then in toasting, has caused the formation of

substances analogous to dextrine and caramel; whereas in (1) the starch has undergone little change during the quick baking necessary to the production of a *white* loaf.

NOTE.—The free flow of saliva can be stimulated if a marble or a clean glass rod be sucked, or if a piece of paraffin gum be chewed.

Train pupils to the habit of testing all digestive fluids, whether natural or artificial, with litmus paper before proceeding to make any tests or experiments. Saliva is not uncommonly acid, instead of alkaline, where dyspepsia or carious teeth are present; if this is not discovered, the experiments will be a failure, as the ptyalin can only act fully on starch under the faintly alkaline reaction which belongs to normal saliva.

Saliva is the first digestive juice to come in contact with the food. The secretions of saliva from the *sublingual, submaxillary* and *parotid glands* differ slightly in composition, but they are all mixed in the mouth.

The action of saliva is two-fold—physical and chemical. The physical property is exercised in keeping moist the mucous membrane of the mouth, assisting in the solution of soluble substances, such as sugar or salt, and in lubricating the bolus of food to facilitate swallowing. It is assisted in this work by the tongue and teeth, by which agencies food is masticated, broken up, and again collected into a form convenient for swallowing. The chemical action of saliva is due to its active, amylolytic, unorganised ferment *ptyalin*, which splits starch granules into *dextrin* and *maltose*; a power also exercised, though much more slowly, on glycogen (animal starch). Upon cellulose ptyalin has no effect, hence it cannot convert raw starch into dextrose. The amount secreted daily is about 1,700 c.c. (3 pints).

Bunge points out, in his "*Physiological and Pathological Chemistry*," that the process of starch digestion is by no means so simple as it was formerly imagined to be. The amount of sugar produced forms but half of the entire weight of the starch, and this sugar is not *grape sugar* but *maltose*. The remainder is *dextrin*, of which there are two varieties, one of which is coloured red by iodine, while the other remains colourless. Thus, starch flour is not altered by the digestive ferments of the saliva and of the pancreatic juice, in the same way as it is if boiled with dilute sulphuric acid, when, by a process of hydration, it is completely converted into grape sugar (*dextrose*).

II.—The Action of Gastric Juice upon Proteids.

MATERIALS: *Artificial gastric juice; pepsin;* 2% *hydrochloric acid; hard-boiled egg; copper sulphate; bicarbonate of soda; chemical tests for Proximate Principles* (*pp.* 165, 173, 175, 176)*; caustic potash; litmus paper; ice.*

APPARATUS: *Test tubes; glass rod; bowl; Bunsen burner; sand-bath; retort-stand.*

(*A*) (1) Test some artificial gastric juice with litmus paper, and compare the reaction with that of saliva.

(2) Label four test tubes (*a*), (*b*), (*c*), (*d*), half-fill each with water and add about half the quantity of artificial gastric juice.

(3) Boil an egg hard, mince the greater part of the white, and if possible rub it through a fine sieve.

(4) Put some of this minced egg into the test tubes (*a*), (*b*), and (*c*); into (*d*) put a few large pieces of the hard-boiled, unminced egg albumin.

(5) Then proceed as follows:—Add to (*b*) a pinch of bicarbonate of soda, and place it with (*a*) and (*d*) in a warm water-bath, of which the temperature must not exceed 37·8° C. (100° F.) for one hour; stir the contents of each test tube at frequent intervals, in order to reproduce the churning action caused by the movements of the muscular coats of the stomach.

Place (*c*) in ice-water for the same period, then transfer it to the warm water-bath for one hour.

(6) Divide the contents of (*a*) into three parts. Test one part for the presence of proteid; compare the result with the control tests (*page* 168).

To the second part add one drop of copper sulphate (use a glass rod for the purpose), and a few drops of strong caustic potash. The rose-red colour indicates the change which proteid matter undergoes in the process of digestion, when it is described as *peptones* (*page* 169).

Place the third portion in a dialyser (*page* 25). Test after 24 hours for evidence of diffusibility by withdrawing a few drops of the water from the beaker, and testing for the presence of peptones.

What light is thus thrown upon the statement that gastric juice converts insoluble proteids into soluble peptones?

(7) Test (*b*) and (*c*) in a similar way for the presence of proteids or of peptones.

The results will show that gastric digestion requires a slightly acid medium and a temperature about that of the human body in health, the process being arrested in an alkaline medium or at a low temperature.

(8) Compare the appearance of the contents of (*a*) with those of (*d*), which will illustrate some of the digestive difficulties associated with imperfect mastication.

NOTE.—The juice secreted by the gastric glands of the stomach is chiefly water containing a *ferment*, or *enzyme*, called *pepsin*, and a small amount of acid. It acts on proteid substances, converting them into peptones, a process which, in the case of milk, is preceded by the curdling due to rennet, a ferment also present in the gastric juice. It has no chemical action on starches, though the small amount of free hydrochloric acid present (0·02 %) suffices to stop the process of starch digestion by the ptyalin of the saliva on the exterior of the swallowed masses.

Mention should be made of the antiseptic action of gastric juice, for putrefactive processes rarely occur in the acid medium of the stomach; the organisms responsible for such processes, though swallowed with the food, being to a large extent destroyed, and the body thus protected from their action.

The proteid envelopes of fat globules are dissolved by the gastric juice, though it has little or no chemical action on fats; cane sugar is, however, inverted by the hydrochloric acid present, probably assisted by inverting ferments contained in the vegetable food consumed.

There are certain intermediate steps in the conversion of proteids into peptones; the substances formed in one of these are described as pro-peptones or *proteoses*; while another of these intermediate steps produces *parapeptone* (*cf. page* 170).

Artificial gastric juice can be prepared by removing the mucous membrane from a pig's stomach and shredding it into a vessel containing 0·4% hydrochloric acid solution. The vessel must be kept in a water-bath for twelve hours at a temperature of 40° C. (104° F.); the extract can then be filtered off and it will contain the ferment pepsin. For experimental purposes, however, it is more convenient to use what is known as commercial pepsin.

III.—The Action of Intestinal Juice on Food.

MATERIALS: *Artificial pancreatic juice; shreds of cooked meat; egg albumin; gum acacia (gum arabic); butter; bread; fresh ox-gall; olive oil; boiled starch solution; caustic potash solution; litmus paper; chemical tests for the Proximate Principles* (*pp.* 165, 173, 175, 176).

APPARATUS: *Test tubes; Bunsen burner.*

(*A*) *Pancreatic Juice.*

(1) Test some artificial pancreatic juice with litmus paper, and record the reaction obtained.

(2) Label six test tubes (*a*), (*b*), (*c*), (*d*), (*e*), and (*f*). Place in:—

(*a*) 15 c.c. pancreatic juice, *plus* a few shreds of meat.

(*b*) 15 c.c. pancreatic juice, *plus* 10 c.c. boiled starch solution.

(*c*) 15 c.c. pancreatic juice, *plus* one gram of butter.

(*d*) 15 c.c. pancreatic juice, *plus* a few crumbs of bread and butter and a few shreds of meat.

(*e*) 15 c.c. pancreatic juice and shreds of food stuffs as in (*d*), *plus* a few drops of hydrochloric acid.

(*f*) 15 c.c. pancreatic juice and shreds of food stuffs as in (*d*).

Place all but (*f*) in the water-bath at a temperature of 37·8° C. (100° F.) for one hour, stirring at intervals.

Place (*f*) in ice-water for the same period, then transfer to the water-bath for an hour, keeping it at a temperature of 37·8° C. (100° F.).

Compare the appearance of the contents of (*d*), (*e*), and (*f*).

(3) Then divide :—

(*a*) Into two parts, and test them respectively for proteid and for peptone (*pp.* 168-9).

(*b*) Into two parts, and test these also respectively for starch and dextrose (*page* 173).

(4) Prepare three dialysers (*page* 25), place in them the contents respectively of (*d*), (*e*), and (*f*), and test the surrounding water after 24 hours for evidences of diffusibility as directed, II. (6), *page* 191.

(5) Take a little butter in a test tube and add some fresh ox-gall to it. Warm the mixture slightly, shake well, and add a few drops of caustic potash solution. Shake again, and note the series of changes which take place in the butter during the process.

Compare the results with those to be seen in (2) (*c*).

NOTE.—It will be observed that the action of pancreatic juice is very comprehensive as it has the power of digesting proteids, fats, and carbohydrates by virtue of the four organic ferments it contains. These are (1) *trypsin*, a more powerful, rapid proteolytic enzyme than pepsin ; (2) *amylopsin*, or pancreatic diastase, so powerful a ferment that it will even act on raw starch—it is absent from the pancreatic juice of infants ; (3) *steapsin*, a fat-splitting ferment, and (4) a milk-curdling ferment, not often called into play, as milk has generally been curdled by the rennin of the stomach. The alkalinity of the juice is due to phosphates and carbonates, while sodium and potassium chlorides are also present.

Steapsin is not soluble in glycerine, so a watery not a glycerine extract of pancreas must be used for these experiments.

(*B*) *The Action of Intestinal Digestion on Fats.*

(1) *Emulsification.* Take three test tubes (*a*), (*b*), (*c*). Place in :—

(*a*) 5 c.c. olive oil, *plus* 5 c.c. water.

(*b*) 5 c.c. olive oil, *plus* 5 c.c. water, plus 5 c.c. strained egg albumin.

(*c*) 5 c.c. olive oil, *plus* 5 c.c. water, *plus* 5 c.c. gum acacia solution.

Shake each mixture very thoroughly; set aside, and observe whether the milky-white appearance present during the shaking process (owing to the distribution through the mixture of the oil globules), is retained in each case after five minutes, after one hour, and after 24 hours.

(2) *Saponification.* To 5 c.c. olive oil in a test tube add 10 c.c. of a 20% solution of potash. Shake well, and continue to shake the test tube at frequent intervals for twenty minutes. Add 10 c.c. water; set the mixture aside as directed in (1), and compare it later with the emulsions made with egg albumin and gum acacia.

NOTE—In the process of saponification a chemical reaction occurs, the fats split up into substances from which they are formed (fatty acids with glycerine), the final products being glycerine and a compound of the base with the fatty acid, which is called a soap. The change which fats undergo in the body is, however, quite different from saponification. It is a physical not a chemical change; the fat is broken up into very small globules which are held in suspension, the emulsion thus formed being of a temporary character as in (1) (*a*), or permanent, as in (1) (*b*) and (*c*). Emulsification is assisted by the presence of an alkaline solution, a free, fatty acid or of some viscous substance, such as egg albumin or gum acacia. Milk offers the most familiar example of a permanent emulsion.

By the action of the pancreatic ferment, fat molecules take up water and split up into glycerine and fatty acid. This process of fat decomposition goes on very slowly, but it appears that if a minute portion of the fat be thus split up the whole is then rendered capable of emulsification, in which form it passes through the intestinal wall.

The emulsification is brought about thus:—Only neutral fats can be *saponified*, *i.e.*, split up into glycerine and salts of fatty acids to form soaps by free alkalies. Perfectly fresh, neutral fat cannot be *emulsified* by a solution of carbonate of soda. If however, rancid fat be taken, or if a small amount of free, fatty acid be added to the neutral fat, an emulsion of microscopically small drops immediately results. Carbonate of soda is present in the pancreatic juice, and analysis of the

ash shows that the secretion contains more sodium than is necessary for the saturation of the strong mineral acids present.

The actions of pancreatic juice, of bile, and of the *succus entericus* are collectively described as intestinal digestion. Reference has already been made to the complex action of pancreatic juice.

Though the uses of bile are considered to be largely excretory in character, its principal action is now stated to be as a coadjutor to the pancreatic juice. That it possesses the antiseptic property popularly attributed to it seems very doubtful; for bile itself is readily putrescible; it is more probable that, by increasing absorption, bile diminishes the amount of putrescible matter in the intestine. It is alkaline, and a solvent of fatty acids, while it assists the digestion of fats.

Recent investigations by Starling, Pawlow, and other physiologists have proved *succus entericus* to be an intestinal juice of the highest importance; one of its main functions is to reinforce and intensify the proteolytic power of pancreatic juice, for, when mixed, these juices act as a most powerful digester of proteid matter, though neither possesses the property when apart from the other.

Halliburton impresses the fact that as the intricacy of the digestive process is increasingly realised so also is "the beautiful adjustment in the quantity and composition of the various juices to the kind of work they have to do" more fully perceived; each link in the long chain follows its predecessor and unites to its successor in orderly fashion; not one can be omitted or tampered with without serious interference with the accomplishment of the work they are designed to fulfil; for each in turn acts as a forerunner, intermediary, and stimulator to its successor.

"For example, the acid gastric juice reaches the small intestine, and there produces *secretin* from its forerunner; the secretin is taken by the blood-stream to the pancreas, where it excites a flow of pancreatic juice; this juice arrives in the duodenum ready to act on starchy substances and on fat. With the assistance of the bile, fatty acid is liberated, which in its turn forms more secretin, and so more pancreatic juice. The pancreatic juice, however, cannot act on proteids without *enterokinase*, which is supplied by the succus entericus; this sets free the trypsin; and trypsin effectively carries out digestive proteolysis."—(Halliburton's "*Handbook of Physiology*.")

It cannot be too strongly borne in mind that, as the digestive processes are very complex, being mainly due to the action of unorganised ferments and their products and combinations, any attempt to reproduce the results artificially can be but imperfect and only partially successful. It is now known that the final products in the living organism are different from those produced by artificial digestion outside the body.

As in all fermentations, the decomposition is always accompanied by hydration, *i.e.*, all the ferments are soluble in water, all may be precipitated from their aqueous solutions by alcohol, and are again dissolved by water after their precipitation. Certain of them, as pepsin, do not diffuse through animal membranes; while each developes its maximum activity at a definite temperature, which varies according to the source from which it is derived. The diastatic ferments of the pancreas and saliva act most quickly at from 37·8° to 40° C. (100° to 104° F.) and are destroyed when in aqueous solutions, if heated to more than 70° C. (158° F.). In a dry state they retain their power, even when exposed to very high temperatures.

IV.—Aids to Digestion.

MATERIALS: *Hard boiled egg albumin; clean handkerchief, or piece of butter muslin; artificial gastric juice; dry powdered sugar; dry, hard biscuit.*

APPARATUS: *Test tubes.*

(*A*) *Mastication.* Take four test tubes (*a*), (*b*), (*c*), (*d*). Place in:—

(*a*) and (*c*) a solid piece of egg albumin.

(*b*) and (*d*) a similar quantity of the albumin, finely minced.

To each add 10 c.c. gastric juice.

Keep (*a*) and (*b*) cool and still for one hour.

Place (*c*) and (*d*) in a water-bath kept at a temperature of 37·8° C. (100° F.) and stir or shake frequently.

Compare the results in each case, and draw conclusions as to the influence of mastication, suitable temperature, and movement upon the digestive process.

(*B*) *Saliva as a solvent and lubricant.*

(1) Wipe the inside of the mouth (especially the tongue) quite dry with a clean handkerchief, or piece of butter muslin. Eat a small quantity of dry, powdered sugar; how do the sensations differ from the normal?

(2) Again wipe the inside of the mouth dry. Eat a large piece of dry, hard biscuit; how are the acts of mastication and swallowing affected?

XI.—ELEMENTARY STUDY OF THE PROCESS OF METABOLISM (*contd.*).

PART II.—THE ORGANS OF EXCRETION; THE SKIN AND KIDNEYS.

I.—The Skin, its Structure, Functions and Excretions.

MATERIALS: *Hand lens; printers' ink; needle; white paper; rubber finger-stall; cotton wadding; bladder; soap; towel; rubber tubing; red thread; muslin; dilute permanganate of potassium solution; methylated spirits; water; vinegar.*

APPARATUS: *Glass jar; thermometer; clinical thermometer; two china plates or small pieces of metal; pipette; piece of clear glass; sand-bath; Bunsen burner; retort stand.*

(*A*) (1) First examine the skin on the palm of the hand and then on the back with a good lens. Notice:—

- (*a*) The larger furrows or creases; determine what causes them.
- (*b*) The smaller ridges (*papillæ*) or furrows. What uniformity is to be detected in their arrangement on different portions of the hand?
- (*c*) The openings of the sweat glands; make careful observations as to any evidence of their function, or any variation in their numbers in different areas. Can they be found in all parts of the hand?

(*d*) The hairs, their colour, length and direction. To what parts of the hand are these confined?

NOTE.—In the palm of the hand the ridges of the epidermis correspond to the rows of papillæ of the *dermis* beneath.

The papillæ are irregularly placed over most of the dermis, and there are no corresponding elevations of the epidermis.

The pores, or orifices of the sweat glands, can be detected in rows on the ridges. It is estimated that there are 500 to every square centimetre on the palm of the hand, while on the back of the body and the neck their number is only about 75 to a square cm.

(2) Spread a thin film of printers' ink on a slip of glass. Press the tips of the fingers and thumb on the ink and then on a piece of clean paper.

Study the print and compare the result with the finger-prints of others. Do the results of these comparisons confirm the assertion that the finger-prints vary in each individual, but in him are invariable? For this reason they are employed for the identification of criminals.

(*B*) (1) Enclose one finger for half-an-hour in a clean, dry, rubber finger-stall. Examine the inner side of the rubber for any evidence of change.

Rinse it out with a very dilute solution of permanganate of potassium, and compare the result with that obtained by the introducing of any dilute form of organic dirt into a portion of the same solution.

NOTE.—Care is necessary to remove any traces of the permanganate of potash solution from the finger-stall after this demonstration, or the rubber will be injured. It will be advisable to neutralize the alkali by rinsing with a dilute solution of vinegar.

(2) Place one hand in a clean, dry, glass jar, which has been kept in a cold place; wrap a length of cotton wadding round the wrist so that the mouth of the jar is entirely closed when the hand is inserted.

Observe the evidence of *insensible* perspiration which appears in a short time within the jar.

(3) To illustrate *insensible* perspiration, fill a bladder with water at 37·8° C. (100° F.) and suspend it in the air. Watch for any evidence of evaporation.

NOTE.—A bladder exhibits no sensible pores, yet the water gradually oozes through its walls and disappears by evaporation. Huxley compared the skin to such a bladder full of hot fluid.

The amount of insensible perspiration is about 1,250 c.c. (1 quart) in 24 hours, but it varies (1) according to the temperature and humidity of the air; (2) according to the condition of the blood, *i.e.*, whether much or little fluid is consumed; (3) according to the character and amount of muscular exercise; and (4) according to the action of certain drugs. It is diminished by belladonna but increased by opium or camphor.

(4) To represent a sweat gland, take about 30 cms. (12 inches) of fine rubber tubing; close one end and twist a length of about 15 cms. from this end into a globular knot.

Lace and net a quantity of coarse, red thread round and between the coils of the knot to represent the capillary vessels with which sweat glands are richly supplied.

As the blood flows in the capillaries it gives off lymph, and the cells which form the walls of the gland absorb waste matters from the lymph which are excreted on the epidermis. Among these may be mentioned *urea*, now conclusively proved to be present in the sweat of healthy persons.

(*C*) (1) Allow one or two drops of methylated spirits to fall on the back of the hand. Notice the sensations which follow. Compare these with the result of the following experiment.

(2) Note the temperature of a thermometer. Tie a strip of muslin round its bulb, leaving one end of the strip free. Immerse the free end in a small quantity of methylated spirits.

Observe the index of the thermometer during the experiment, especially as the muslin dries.

What evidence is afforded of the results of rapid evaporation?

(3) Take two china plates, or small pieces of metal, (*a*) and (*b*). Place (*a*) on a sand-bath or in an oven until very thoroughly heated.

Fill a pipette with cold water, and allow a shower of drops to fall alternately on (*a*) and (*b*). In which case is evaporation the more rapid, and how can this observation be applied to the relative risks of exposing the body to a current of air when cool or when heated after violent exercise?

NOTE.—It is well known that the most important function of sweat is to regulate the loss of heat from the body. In cold weather the *vaso-motor nerves* constrict the vessels of the skin and relatively little secretion of sweat takes place, whereas in hot weather bodily heat is relieved by the evaporation of large quantities of perspiration. When the atmosphere is saturated with moisture, whether at a high or low temperature, evaporation from the skin proceeds very slowly and is associated with vague feelings of oppression and discomfort, which express themselves as weariness, fidgets, mental denseness, impatience, etc.

The risk to health which follows getting wet through or sleeping in damp beds exists in the resulting rapid evaporation of the moisture, which chills the body and lowers its temperature.

(*D*) (1) Take the body temperature with a clinical thermometer by holding it under the tongue for five minutes.

(2) Pour a mixture of methylated spirits and water or vinegar and water, over both hands.

Immediately repeat (1) and compare the records. Does this support the statement that the wrists and ankles should be well protected in cold weather?

NOTE.—Except in disease, the variation in the temperature of the body is very small, being little influenced by season or mode of life, but the rate of heat production varies widely, therefore the rate of heat loss must be equally variable; it has been calculated that were it not so the body temperature would reach boiling point in thirty-six hours. The body loses heat by radiation, by conduction, by convection, by evaporation, and through the excretions from the lungs, skin, kidneys, and intestines. Of the total amount of heat lost, 87% is from the skin.

Draw attention to the increased activity of the sweat glands when taking active exercise or when enclosed in a heated chamber, and of the pallor of the skin when sedentary or when "cold," an evidence that heat is being economised, the blood supply to the surface being largely diminished. The regulative mechanism which controls the activity of the sweat glands exists in the nervous system; heat or cold playing on the surface of the skin stimulates those nerves which connect with nerve centres, where, in turn, the stimulus is transmitted to motor-nerves, which run thence to the blood-vessels and glands. This mechanism affords an illustration of nervous reflex action, adapted in this case to conserve the well-being of the organism.

(*E*) Rub or otherwise warm the hands. Press the fingers firmly on a piece of clear glass. State how the measures necessary to remove the indication thus given confirm the fact of the presence of oily matter in the *sebaceous* glands.

NOTE.—It is almost impossible to remove the impress of hot fingers from the glass without hot water, soap, or other solvents of fat. The presence of the cutaneous oil glands preserves the suppleness of the skin, and prevents it, as well as the hair, from becoming too dry. When the excretion is insufficient, or when it is destroyed by the use of strong alkalies, such as washing soda or common soap, the skin cracks and "chaps"; a condition relieved by the use of such preparations as lanoline or cold cream, which supplement the deficiency.

(*F*) (1) Examine the texture and "feel" of the skin by grasping a portion of one or two different parts of the body. Observe that it is tough, elastic, sensitive, and plump; forming an ideal covering for the structures and tissues of the body.

(2) Try to lift the skin away from the underlying tissue in the following places:—the back of the hands; the cheek; the forehead; the neck; the palm of the hand and the fingers.

Note how the skin becomes hard and thick where wear and tear are considerable, or where pressure is intermittent, as on the palms of the hands, on the upper surfaces of the toes (corns), or on the soles of the feet.

NOTE.—A healthy skin is firm and elastic when grasped. The fat felt beneath the dermis acts as a buffer against the pressure of

surrounding objects, and gives roundness and softness to the outline of the figure. The skin can be pinched up and moved about over the deeper structures because it is bound to the *fascia* of the muscles and to the superficial prominences of the bones by "loose bridles" of connective tissue, which permit of very free movement.

(*G*) (1) Run the point of a clean needle under the thin outer layer of the skin on the palm of the hand, also under the thickened skin of the forefinger. Does the result show the presence of nerves and blood-vessels in the outer skin, or epidermis?

(2) Compare this with the result of running the point of a fine, clean needle into the deeper, inner layer of the skin, or dermis.

(*H*) Wash and dry the hands, and then rub the palms briskly together.

Observe the cells of dead epidermis, which appear as a fine powder, removed by this action.

(*J*) Press the fingers of one hand firmly on the back of the other; quickly remove the pressure, and note the difference in colour between the spot pressed and the surrounding skin.

NOTE.—Reference can be made to the control of the cutaneous blood-vessels by the vaso-motor nerves, to the phenomena of blushing and flushing, or to the pallor of fear, as evidences of the vascularity of the dermis, and of the part played by the skin, through the influence of the nervous system, in the expression of the emotions.

II.—The Kidneys, their Structure and Excretion.

MATERIALS: *Sheep's kidney (the butcher must be specially directed to supply the kidney with the surrounding fat, otherwise the tubes and blood-vessels will be cut away); thin rubber sheeting; red yarn.*

APPARATUS: *Dissecting instruments and board; thistle funnel.*

(*A*) *Examination of a Sheep's Kidney.* Cut away most of the fat surrounding the kidney, but leave the ureter and blood-vessels untouched. Notice:—

(1) The shape of the organ (*Fig.* 18, *page* 86).

(2) Its size and colour. The dead kidney is much smaller than in life when it is distended with blood.

(3) The tubes (*ureters*) leading from it—white and slender.

(4) The blood-vessels (the *renal* artery and vein), which branch as they enter the kidney; these arteries are relatively wide and short, and carry the blood to this very vascular organ directly from the aorta.

(5) The outer skin.

(6) The fat which supports (3) and (4), which corresponds in appearance with the stem-scar on a bean.

(7) The deep fissure (*hilus*) on the inner border.

(*B*) Slit open the ureter with scissors, and trace it to where it dilates into the cavity of the pelvis of the kidney; this cavity is lined with a whitish mucous membrane, similar to that of the ureter.

(*C*) Beginning at the outer border, split the kidney into halves longitudinally, like the two cotyledons of a bean, and observe:—

(1) The *pelvis* as now exposed, and the cups (*calyces*) or smaller cavities of which it is formed.

(2) The outer wall (*the cortex*), dark brown in colour; study its somewhat granular texture with the hand-lens.

(3) The conical processes of pale kidney substance which project into the pelvis; these are called the twelve *pyramids of Malpighi.* Look carefully at the tiny pits which are the openings of the minute tubules of which the kidney substance is formed.

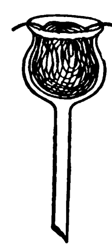

FIG. 42.

(*D*) To illustrate roughly the complex structure of a urinary tubule and capsule, take a thistle funnel; lower into the bulb a small bag made of thin rubber sheeting, and fasten it round the rim of the funnel; this represents the capsule (*Fig.* 42). Make a little ball of red yarn, with two free ends,

Suspend this in the bag hanging in the funnel to represent a globular tuft of capillaries; the free, projecting ends roughly represent the artery which enters and the vein which leaves each capsule.

NOTE.—The unit of structure in the kidney is a tube which draws material from surrounding blood-capillaries. The relation of one to the other is peculiar. The inner end of the tube, which is of microscopic fineness, is enlarged into a ball, which is deeply depressed opposite the point where the tube leaves it. Into this depression depends a network of capillaries. A number of these primary tubes unite, and many of their common ducts open at the apex of each of the Malpighian pyramids and empty their secretion into the pelvis of the kidney. Water, salts and other substances contained in the blood which circulates in the tuft of capillaries, pass through into the cavity of the capsule and so down the tube to be excreted.

The kidneys have been compared "to a piece of skin rolled up with its outer surface turned inwards. Its glands would then pour their secretions into a cavity where they might accumulate, instead of evaporating as fast as they are poured out." There is a very close relation between the work of the kidneys and that of the skin. Everyone is familiar with the effect of hot and cold weather upon the relative amount of the secretions of the skin and kidneys; the one organ of excretion supplements the work of the other, and both co-operate in maintaining what is known as the physiological balance.

III.—Observations on Urine.

MATERIALS: *Fresh urine; neutral litmus paper; alcohol; copper sulphate; nitric acid; silver nitrate solution; hydrochloric acid; barium chloride; caustic potash; ammonia; ammonium molybdate.*

APPARATUS: *Glass rod; small gas jar, or narrow glass cylinder; hydrometer; porcelain evaporating dish; test tubes: air-oven; c.c. measure; watch glass; balance; Bunsen burner.*

(*A*) *The General Character of the Urine.*

(1) Observe the colour. This varies, in good health, with the degree of concentration.

(2) Test the reaction. Place a drop of urine on neutral litmus paper with a glass rod.

NOTE.—The reaction of normal urine is acid, but if stale, or during digestion, it may become alkaline.

(3) Take the specific gravity. Nearly fill a small gas jar or narrow glass cylinder with urine. Gently introduce a hydrometer; it should record a specific gravity from 1·015 to 1·025. Compare this with the specific gravity of water by repeating the experiment with water instead of urine.

(4) Note the large proportion of water. Carefully weigh a porcelain evaporating dish. Nearly fill it with urine, and weigh again, recording the weight. Evaporate very carefully to dryness in the air-oven. Weigh again. The solid residue consists of urea and salts; the loss of weight denotes the amount of water contained in that quantity of urine.

(*B*) *Some Constituents of Urine.*

(1) Test for the presence of *urea*. Evaporate 20 c.c. of urine to a quarter of its volume. Pour into a test tube, cool, and add one drop of fuming nitric acid.

Note the effervescence due to the breaking up of the urea, as it is decomposed by the *nitrous acid* (an impurity present in the nitric acid), carbonic acid, nitrogen gas, and water being given off.

(2) Test for the presence of *inorganic* salts in urine. Take four test tubes, (*a*), (*b*), (*c*), and (*d*), and half-fill each with urine.

Acidulate (*a*) with five or six drops of nitric acid; then add a few drops of silver nitrate solution. The white precipitate formed proves the presence of chlorides.

Acidulate (*b*) with one or two drops of hydrochloric acid, and add barium chloride. The white precipitate formed shows the presence of sulphates.

To (*c*) add some liquid ammonia; a white precipitate of earthy calcium and magnesium phosphates is formed, which becomes more apparent on standing.

Mix (*d*) with half its volume of nitric acid; add ammonium molybdate and boil. The yellow crystalline precipitate which falls contains the alkaline phosphates (sodium and potassium) as well as the earthy phosphates precipitated in (*c*).

NOTE.—The object of acidulating (2) (*a*) with nitric acid is to prevent the precipitation of phosphates by the nitrate of silver. Hydrochloric acid is added in (2) (*b*) also to prevent the precipitation of phosphates. As the alkaline phosphates remain in solution in (2) (*c*) it is useful to complete the tests by the addition of (2) (*d*).

(3) Test for *uric acid*. Add 5 c.c. of hydrochloric acid to 100 c.c. of urine. Stand aside for 24 hours; the pinkish-red deposit formed consists of the pigmented crystals of uric acid.

(*C*) *A study of urea, the nitrogenous constituent of urine.*

(1) Concentrate some urine by careful evaporation, as in (*B*) (1); pour a portion into a watch-glass, cool, add a few drops of strong (not fuming) nitric acid, and stir with a glass rod. Crystals of urea nitrate separate out.

(2) Take some urea, prepared as in (1) above, and observe its appearance, taste, and consistency.

(3) Shake up some crystals of urea with alcohol and observe their behaviour.

(4) Repeat (3), only substitute water for alcohol. Test the reaction with litmus paper.

NOTE.—Urea is white, salt, crystalline, very soluble in water, and neutral to litmus paper.

(5) Heat some urea crystals in a dry test tube; notice the smell of ammonia, a proof that urea contains nitrogen and hydrogen. Continue to heat for some time; then dissolve the residue with a very little water. Apply the Biuret test, *i.e.*, add *one* drop of copper sulphate, and *several* drops of strong caustic potash (Fehling's solution) and boil. The residue is the chemical substance *biuret*, from which this test takes its name (*page* 169).

NOTE.—A very large excess of potash is necessary for this test where ammonium sulphate is present.

The quantity of urea present is variable; the normal percentage in human urine is 2%, but this varies according to the degree of concentration of the urine. Until a very recent date it was believed that all the nitrogen of the proteid destroyed in the body (*see* "*Some Properties of Proximate Food Principles*," *vide infra*) was eliminated with the urine, and of this about 90% appeared in the form of urea. It was taught that the total nitrogen eliminated daily amounted to from 95% to 98% and appeared as *urea*, *kreatinin*, *ammonia*, and *uric acid*. Also that the absolute amount of each of these nitrogenous products depended upon the amount of protein broken down in the body, while their relative proportion to one another and to the total nitrogen eliminated from the kidneys remained constant.

Recent investigations by Professor Chittenden, Dr. Neumann and others, have led to a radical change in the teaching on this subject, for they have proved that the relative proportions which the nitrogenous products bear to each other and to the total nitrogen eliminated in the urine change very greatly. The elimination of kreatines, for instance, is just as great when no proteids are consumed in the food as when they enter largely into the daily diet.

Urea, on the contrary, is peculiarly a product of what is technically termed proteid katabolism. When 100 grams of proteid are broken down and eliminated from the body, 90% of the contained nitrogen is present as urea; whereas if the proteid katabolism be reduced to 20 grams a day, not more than from 30% to 60% of this nitrogen appears in the form of urea. The katabolism which yields the kreatinin clearly tends to be a constant quantity for each individual, independent of the food protein; it is therefore held by some physiologists to represent what is called the tissue metabolism.

The katabolism which yields urea chiefly represents, on the other hand, the katabolism of an excessive proportion of proteid in the food, for its percentage in the urine depends directly upon the amount of proteid contained in the food. These authorities therefore hold the opinion that urea represents nothing else than the effort of the human organism to get rid of nitrogen that it does not need and cannot use. "Recent experiments by Chittenden and others have shown that nitrogenous equilibrium in healthy adults can be maintained on a diet containing only half the usual amount of

proteid, and it is in the subjects of these experiments that the excretion of urea has fallen correspondingly, the other nitrogenous constituents of the urine remaining fairly constant. Muscular exercise," says Professor Halliburton, "has little immediate effect on the amount of urea discharged, the major part of the increased nitrogenous waste appears as urea in the urine excreted on the succeeding day."

Chittenden states that uric acid is the product of the successive activities of certain intracellular enzymes, which are at work in the liver, spleen, lungs, and muscles. Another ferment, present principally in the liver, muscles, and kidneys, has the power of oxidizing and thus destroying uric acid, with the formation, among other substances, of *urea*. ("The Nutrition of Man," Chap. II.)

XII.—CUTANEOUS SENSATIONS.—TASTE and SMELL.

Touch. Temperature. Pressure. Muscular sense. Elementary study of taste and smell.

I.—Touch.

MATERIALS: *A selection of small objects in wood, metal, china, silk, and wool; pen; ink; pin; tape-measure; compasses; blotting paper.*

(*A*) (1) Shut the eyes and then allow a companion to place on the outstretched hand some small object, not previously seen or selected. Describe the size and shape of the specimen without moving the hand or using any means of assisting the judgment except the sensations recorded by the palm of the hand.

(2) Repeat the test with the same article, but increase the accuracy of the observation by employing the fingers as assistants to detect every detail of outline, size, texture, temperature, etc. Compare the extent to which the more delicate sense of touch in the fingers has assisted the judgment.

Open the eyes, and observe visually what points have been mentioned or omitted.

Repeat (1) and (2) several times, making use of different and, if possible, unfamiliar articles. Observe how quickly an improvement becomes evident when the sense of touch

is cultivated by practice, especially if it be exercised on several successive occasions.

(*B*) To localise the relative delicacy of touch sensations, blindfold a companion and lightly touch some portion of his body with a pen dipped in ink (or with a hair fixed by sealing wax at right angles to a wooden handle).

Ask him to point out with a blunt pin the point touched as soon as the pen is removed.

Measure the distance with a tape-measure between the ink dot and the point touched with the pin.

Observe whether these distances are always about the same, or whether there are grounds for the statement that the nerves of touch are unevenly distributed over the surface of the body.

NOTE.—The qualities which distinguish an object when touched are believed to depend upon the intensity, duration, and extent of a sensation. The prick of a needle for example, produces an acute though very localised sensation; hard substances give impressions of resistance, soft or sticky substances yield or adhere. Good or bad conductors give sensations of cold or heat.

(*C*) (1) Rest the blunt points of a light pair of compasses on the skin of various exposed parts of the body, noting these parts which can best distinguish the blunt points as *two* points of contact, and constantly re-adjust the instrument so that the distance between the points is varied. Repeat the test upon the same surfaces under these varied conditions.

Among the parts tested in this way should be the tip of the tongue, the nose, the fingers, the eyelids, the cheeks, the forehead, and the neck.

(2) Draw the compasses gently up the palm of one hand to the tip of a finger. Does the sensation experienced coincide with the known fact that the distance between the points of the compasses remains constant?

(3) Repeat the test upon the bare arm. Are the points of the compasses recognised as *two*, when kept at the same distance apart, as they are drawn up the long axis of the arm, or is the sensation of two points of contact more distinct when the compasses are moved transversely across the limb?

(4) Moisten the skin of the hand and arm, then repeat (2) and (3). Is the sense of touch more or less delicate when the skin is dry or when it is moist?

(*D*) (1) Close the eyes, and call on a companion to touch one of the fingers of either hand. Is it easy to indicate correctly which finger, or which portion of one, has been touched?

(2) Bare one foot, and have the test repeated with either the second, third, or fourth toes. Is accurate indication as easy as in (1)?

NOTE.—It would be of interest to compare Weber's Table of the tactile sensibility of different parts with the results obtained by a class of students. His measurements indicate the least difference at which the two points of a pair of compasses could be separately distinguished, and vary from 1 mm. ($\frac{1}{24}$ inch) at the tip of the tongue to 62 mm. ($2\frac{1}{2}$ inches) on the mid-dorsal region, In the case of the limbs, the compass points had to be further apart before they were recognised as *two* when the line joining them was in the long axis of the limb, than when in the transverse direction. When the points of the compasses are slowly drawn up the hand to the tip of the finger, the impression is very strong that the distance between the points is increasing instead of remaining constant, a consequence of the different degree of sensitiveness possessed by the different parts touched. The skin becomes more sensitive when moist, a fact familiar to artizans or mechanics, who frequently moisten the ball of the thumb, for instance, to test the edge of their tools or the sharpness of their instruments.

The fingers are constantly in view, and habitually used individually, consequently the brain has been trained to register minute differences in the qualities of the sensation of touch transmitted, whereas the toes are rarely seen;

indeed, when uncovered, the toes specified are much more often moved together to examine an object than separately; the detection of slight variations of touch sensation in the toes has consequently not become habitual in the brain. In most touch sensations the eyes assist the judgment; hence where this assistance cannot be rendered, exaggerated sensation are often experienced; for instance, the size of a pimple on the cheek or ear when touched by the fingers, or the size of a cavity in a tooth when explored only by the tongue.

(*E*) Prepare some small pieces of blotting paper of several sizes, from about 1 to 10 cms. (½-in. to 4-in.) square. Drop these from a height of 30 cms. (1-ft.) on to various exposed surfaces of a companion's body, as the forehead, the fore-arm, the back and palm of the hand, the back of the neck, etc.

Find in each case what sized piece is necessary to produce a sensation of impact, and note how this varies in the parts indicated.

NOTE.—The quality of skin sensations depends, it is believed, upon the presence or absence of hairs and other differences in the structure of the skin.

The number of nerve endings in the skin is not the only factor in sensations of touch. Halliburton points out "that an important rôle is played by what he calls 'local signature.'" Minute areas of the body surface have each their local sign, *i.e.*, the sensation arising from one area differs in some obscure quality from the sensation arising from stimulation of neighbouring areas, thereby enabling us to identify each area when stimulated. The whole surface of the skin has been mapped out into areas which respond to stimuli of certain kinds, as for example, those of touch, pain, heat, or cold, while they are insensitive to others. It must never be overlooked that the nature of the conscious impression, described as a sensation, depends upon the brain area to which the afferent nerve carries the stimulus. For example, any form of stimulus applied to the optic nerve causes a sensation of light or to the gustatory nerves, of taste.

It is useful to illustrate the fact that if a *constant pressure* be applied equally to all parts of the surface of the skin, there is no *sensation of touch*. To demonstrate this phenomenon, prepare a large basin containing water of the same

temperature as the body (37° C., 98° F.). Direct a pupil:—

(1) To immerse the whole hand gently, and to keep it quietly in the water; no "touch" sensation will be felt.

(2) To repeat the process, agitating the water roughly; the sensation of touch is stimulated by the impact of the oscillations against those areas of the skin which respond to this form of stimulus.

II.—Temperature.

MATERIALS: *Metal rod; red and black ink; pen; water.*

APPARATUS: *Beaker; Bunsen burner; thermometer.*

(*A*) To localize the skin areas which are sensitive to heat or cold, take a blunt-pointed metal rod and dip it in very hot water. Bare the arm, and rapidly touch numerous different points on the anterior surface. Is any variation of sensation to be observed at these different points?

Mark with red ink the spots where the sensation of heat is most acutely felt.

(*B*) Place the metal rod in iced water for a few minutes; then repeat the test described in (*A*); mark with black ink the spots where the sensation of cold is most pronounced.

Observe to what extent, if any, the red and black spots coincide; are they evenly and equally or irregularly distributed over the area of skin tested?

(*C*) Repeat I. (*C*), but warm the points of the compasses. Notice if the distance requires to be increased or diminished at which the points are distinguished as *two* when applied to the skin. Make the test over the areas mapped out in red or black ink in II. (*A*).

NOTE.—The surface of the skin has been described as "a mosaic of tiny sensorial areas," not set edge to edge but separated by relatively wide intervals. Each spot subserves a specific sense—touch, pain, cold, or heat—according as it coincides with the site of some special end organ, but all are intercommingled, though in some localities one variety predominates, in others another does so.

III.—Pressure and Muscular Sense.

MATERIALS: *Gram weights up to 1 kilogram; brick; cardboard discs, 5 cms. (2 in.) diameter; balance.*

(*A*) (1) Extend the hand, palm upwards, and place on it a 28 gram (1 oz.) weight.

Ask a companion to add small weights in succession; note, during the process, what is the smallest difference between the original weight and the amount added which produces a sensation that can be detected.

(2) Repeat the test upon the hand of a companion. Is the amount of additional weight required, before a sensation of increased weight is experienced, alike in both cases?

(*B*) Weigh a brick. Again extend the hand and support the brick on the palm of the extended hand, as in (*A*); then have small weights added in succession. Notice the sum of the additional weights required to give rise to a sensation of increased weight.

Does comparison of the additional proportions required to cause a sensation of increased weight in (*A*) (1) and (*B*) (relative to the original mass of the weights) suggest that there is any ratio between the two.

(*C*) (1) Place the back of one hand flat upon the table and rest a disc of cardboard, 5 cms. (2 in.) in diameter, upon the palm of the hand. Should the sensation experienced be described as one of contact or of pressure?

(2) Keep the hand in the same position, but place a kilogram weight upon the cardboard disc. Which of the two terms, contact or pressure, accurately describes the sensation now experienced?

(3) Raise the hand from the table without removing the heavy weight. The feeling of resistance to effort which is experienced by the hand is described as the "muscular sense."

NOTE.—Recall Weber's law, "An increase in a stimulus sufficient to call forth a conscious increase in the sensation must always

bear the same ratio to the original strength of stimulus to which it is added." If, for instance, to a weight of 1 oz. an addition of $\frac{1}{5}$th oz. is sufficient for the subject of the experiment to detect an increase in the weight supported, then if a weight of 5 oz. be used, the addition of 1 oz. will be necessary to produce a corresponding increase of sensation.

The magnitude of the fraction representing the increase of stimulus necessary to produce an increase of sensation determines what is called the *discriminative sensibility*, which differs considerably for different sense organs. Thus for light it is $\frac{1}{100}$; that is to say, that if a room were lit by 100 candles, the addition of one candle more would be perceptible to the eye; whereas if the room were lit by 1,000 candles, 10 more would be required to make the eye conscious of the increased illumination. Or on the other hand, one candle in the first case and 10 candles in the second would have to be removed before any diminution in the brilliancy of the illumination would be perceived by the eyes. The fraction of this discriminative sensibility is stated, on good authority, to be in the case of weight $\frac{1}{40}$ to $\frac{1}{75}$ for different muscles, and in the case of tactile pressure $\frac{1}{10}$ to $\frac{1}{30}$ in various parts of the body.

(*D*) Close the eyes and concentrate the attention on the position of the right hand.

What information in respect of sensations of contact, muscular effort, etc., is gained by means of:—

(1) The nerves of the joints;

(2) The nerves of the tendons;

(3) The sensory nerves of the muscles;

(4) The tactile nerves of the skin;

(5) The sensations which accompany change of position?

NOTE.—(1) Affords information as to how far articular surfaces are in contact.

(2) Indicates which muscles are flexed or extended.

(3) Estimates the effort required to support the weight of the hand.

(4) Records whether the palm or fingers are in contact either with each other or with some foreign body.

(5) Indicates the character and extent of the movement.

Adaptation plays an important part in all sensations. The fact is familiar that the same room feels warm to a person entering it from the outside when the atmosphere is raw and the temperature low, while it feels chilly to someone else who comes into it from a greenhouse. Heavy weights, again, feel the heavier when a light weight has just been handled, and the contact of wool with the delicate skin of an unaccustomed wearer is at first as unbearable and later on as unperceived as is the first wearing of false teeth.

Ordinarily many forces that are constantly acting upon us are unnoticed; sounds are ignored, pressure disregarded, objects unperceived, though it is a physiological fact that each sensation leaves its impression on the nervous system. Experience and experiment continue to prove that no impression is ever wholly forgotten, never entirely obliterated from the nerve cells where it is recorded. The individual may fail to recollect but the brain records and remembers, a fact which demands more general recognition by those responsible for the environment of young people, for sudden strong stimuli may and do, awaken such unremembered records into conscious recollection by which conduct is influenced for good or ill.

IV.—Taste and Smell.

MATERIALS: 10 *grams salt; pepper; sugar; coffee and chocolate fondants;* 2 *apples* (1 *raw,* 1 *cooked*)*;* 2 *potatoes* (1 *raw,* 1 *cooked*)*;* 2 *onions* (1 *raw,* 1 *cooked*)*;* 1 *carrot;* 1 *cabbage; a small, fresh fish;* 10 *c.c. solutions of sugar, quinine, vinegar, camphor and salt; camel-hair brush; water, hot and cold.*

APPARATUS: *Beakers; bowl; thermometer.*

(*A*) (1) Close the eyes and nostrils; then try to distinguish between very small pinches of salt, pepper, and sugar placed in the mouth by a companion.

(2) With the eyes and nostrils still closed bite samples of the following fruits and vegetables, handed to you by a companion in a previously unknown sequence.

(*a*) A raw apple.	(*d*) A cooked apple.
(*b*) A raw potato.	(*e*) A cooked potato.
(*c*) A raw onion.	(*f*) A cooked onion.

To what extent is flavour detected apart from odour; and to what degree does the identification of these samples depend, under the above conditions, upon sensations of texture (*e.g.*, crispness), rather than of taste or smell?

(3) With eyes and nostrils still closed endeavour to detect any difference in flavour between coffee and chocolate fondants, supplied by a companion.

(4) Test the samples supplied, and state which of the substances have taste and which have odours:—Dilute solutions of vinegar and of camphor, small pieces of carrot, onion, cabbage, and fish.

NOTE.—It is necessary for odorous substances to be in a gaseous state in order to act upon the olfactory epithelium, as odours are propagated mainly by diffusion. The mucous membrane must be neither too dry nor too moist, *e.g.*, odours and flavours are unperceived when an individual is suffering from a severe "cold in the head." Some persons are congenitally insensible to one or more odours, while to others they react normally. The delicacy of the sense of smell is most remarkable. It is calculated that even $\frac{3}{1000000000}$ of a grain of musk can be distinctly detected. Ammonia is unsuitable for olfactory experiments, because, like other pungent substances, it stimulates the endings of the fifth nerve as well as those of the olfactory, and thus confuses one sensation with others.

(*B*) Wash the mouth out with lukewarm water.

(1) Place a little powdered sugar on the tip of the tongue. Is the sweetness at once apparent?

(2) Prepare weak solutions of (*a*) sugar, (*b*) quinine, (*c*) salt, (*d*) vinegar, the temperature of which should not exceed 35° C. (95° F.), or be less than 10° C. (50° F.) Dip a clean brush in (*a*) and paint the tip, the sides and the back of the tongue. At which locality is the sweetness most noticeable?

Wash out the mouth with clean, lukewarm water and repeat with (*b*), (*c*), and (*d*); make a note of the part of the tongue where at each test sensation of a definite character is most acute.

(3) Repeat (2) but duplicate each test; first, after the mouth has been washed with water as hot as can conveniently be borne, and second, after the mouth has been well washed with ice-cold water.

NOTE.—Solid substances must be dissolved before their taste can be detected. The tip of the tongue is most sensitive to sweets, the back to bitters, the sides to acids; solutions should be fairly concentrated; it will be found that saline tastes are most rapidly perceived.

Extremes of temperature numb the nerves of taste, and temporarily rob them of their sensibility; consequently, nauseous substances can be swallowed without disgust when the nostrils are closed and the mouth previously washed with very hot or very cold water. Tastes are classified as sweet, bitter, acid, and saline.

XIII.—SPECIAL SENSE ORGANS.

(A) THE EYE.

External Observations. Dissection of a Bullock's eye. Power of Accommodation. The "near" point. The "blind spot." Binocular vision. Visual judgments. Retention of Vision. Irradiation. Tests for acuteness of vision. Colour-sense.

I.—Observations on the Eye.

(*A*) *The provision made for the protection of the eyes.*

(1) Note the position of the eyeballs, embedded in fat within the bony orbits, those funnel-shaped cavities which allow full freedom of movement while protecting the delicate structure of the eyes from injury. The eyes are also sheltered by the over-hanging arched eminences of the eyebrows, which are formed of muscles, thickened skin and stiff hairs. These muscles of the eyebrows control, to a certain extent, the amount of light admitted to the eye. Observe that the hairs of the eyebrows are arranged to catch perspiration as it trickles down the forehead and to conduct it from the eyes towards the temples.

(2) The freely-moveable lids, formed of folds of skin containing thin plates of cartilage. Test their power of

involuntary (reflex) movement when any foreign body approaches, or any danger threatens. Which is the larger and which the more stationary of the two lids, the upper or the lower?

NOTE.—The lids maintain their position close to the eyeball in consequence of atmospheric pressure, and move smoothly and freely over the surface of the eyeball.

(3) The incessant winking of the eyelids. This rests the retina, distributes the tears over the eyeball, and assists in pumping the excess of this secretion (consisting of salt, water and mucous) into the *lachrymal sac* or tear-bag, from whence it passes through the nasal duct into the nose.

NOTE.—The angles of the eyelids are called the inner and the outer *canthus*. A small orifice will be found on both lids, close to the inner canthus of each eye, known as the *punctum lachrymala.* The tiny canal which leads from each of these apertures opens into the upper end of the nasal duct, which in its turn communicates with the lower part of the nose. If the *punctum* is obstructed or if tears are secreted too rapidly they overflow and run down the face. Weeping is always associated with contraction of the muscles of the eyelids. These contract on any strong expiratory effort, as during violent coughing or laughing. The flow of tears too, can be reflexly excited by almost any violent sensory stimulation.

(4) The eyelashes, or *cilia*, consisting of short, thick curved hairs, arranged in a double or triple row at the margins of the eyelids; these protect the eyes from undue glare, and from wind, dust, or the access of minute insects, etc. Observe that they are arranged in two curves, in the lashes of the upper lid the convexity is upwards, in the lashes of the lower lid the concavity is downwards. In which lid are the lashes the longer and more numerous? Note the minute openings of the ducts of the small *Meibomian-glands* at the roots of the eyelashes. These secrete an oily substance which prevents adhesion of the lids to the eyeball.

(5) The constant secretion from the *lachrymal* or tear-glands. This fluid moistens and cleanses the surface of the

eyes, and is poured out in larger quantity when specks of irritating matter lodge on the *conjunctiva*, or transparent epithelium, which lines the inner surface of the eyelids and thence is reflected over the front of the eye-ball.

NOTE.—The lachrymal gland is lodged in a depression at the outer angle of the orbit; its ducts, from six to twelve in number, have their orifices so arranged as to disperse the secretion of the gland over the surface of the *conjunctival* membrane.

(*B*) *The range of movement of the eyes.*

Hold the head still, and look at the middle region of the opposite wall of the room. Then test the range of movement possible to the eyeballs (separately and together), as a result of the separate or combined actions of the six muscles by which they are connected to the walls of the eye-socket.

Without moving the head look (1) up to the ceiling; (2) down to the floor; (3) towards each corner of the room; (4) at an object held in one hand; (5) at an object seen out of the window.

NOTE.—Each eye can be moved through an angle of nearly 60° downwards, and of 35° to 45° in other directions. One eye never moves without the other.

It is necessary to distinguish two series of associated movements; (*a*) movements of both eyes in the same direction, (*b*) movements which converge the eyes as when looking at a near object. The amount of effort exerted by the muscles of the two eyes in order to bring them both to bear accurately upon any given visual object is appreciated by the muscular sense. It is by this sense that a just notion is formed of the distance of an object and of its size. The gazer at a near object feels that the muscles of the eyes are exerting an effort of appreciable convergence, whereas when looking at a distant object the visual axes are approximately parallel and a judgement of distance is coincidently formed. *Squinting* is usually the result of a defective power of "accommodation" in either eye or in both, which calls upon the convergence muscles for an exaggerated activity; these muscles become so much developed, in consequence, that they are liable to overpower their natural antagonists on the other sides of the eyeballs. This preponderance of the over-

exercised internal muscles results in the resting position of the affected eye being one of convergence to a near point. Squinting is dependent upon the shape of the eyeball, and is curable either by suitable spectacles, by eye exercises, or by operation.

II.—Dissection of a Bullock's Eye.

MATERIALS: *Two bullock's eyes.*

APPARATUS: *Small square of glass or flat porcelain dish; dissecting instruments and board.*

(*A*) (1) Observe that the eyeball is composed of segments of two spheres of different sizes; of which the larger is opaque, the smaller transparent.

Place the specimen on a small square of glass or on a flat porcelain dish. First trim away the membrane (the *conjunctiva*), which covers the front, or "white" of the eye. This membrane is continuous with the lining of the eyelid when the eyeball is in place. Then proceed to study the muscles as follows:—

(*a*) Trace the *superior oblique* muscle which runs along the roof of the eye-socket, passes through a loop of tendon near the edge of the orbit, and then turns outward and backward to its point of attachment at the top of the eyeball.

(*b*) Find the *inferior oblique* muscle which has its origin in the inner front part of the socket, passes outward, and terminates in the lower surface of the eyeball.

(*c*) The four straight muscles (the *superior*, *inferior*, *internal*, and *external recti*), are attached externally to the four sides of the eyeball; they pass straight forward from the back of the orbit to their respective insertions in front of the eyeball. The superior rectus muscle moves the eye upwards, and the inferior one directs it downwards; the internal rectus moves it outwards and the external rectus inwards. The superior oblique muscle

works with the inferior rectus; the former steadies the eyeball, while the latter pulls it down. In a similar fashion the inferior oblique aids the superior rectus to control the eyeball as it turns upwards.

(*B*) Dissect away the muscles and fat, and find the large, round, white optic nerve; note the place where it enters the eyeball; a little below and to the inner or nasal side of the central point of the posterior curve of the eyeball.

NOTE.—To continue the dissection it is advisable to employ a fresh specimen, as the muscles and fat just removed for the purpose of these observations serve to support the eyeball during the process. It is also advantageous before beginning the dissection to place the eye upon a small square of millboard, to which it adheres. This support can be easily turned and shifted about for purposes of observation. Two methods of dissection are described, either of which can be employed according to the proficiency of the pupils. In the first, the eye will rest the whole time upon the little board, and, after cutting through the *cornea*, should not be touched at all with the fingers. If compressed, or even steadied by the hand, the jelly-like contents are liable to be squeezed out and the dissection is spoiled. In the second, the specimen will be transferred at an early stage to a flat glass dish of water.

III.—Method I.

MATERIALS: *Bullock's eye; slip of newspaper; tissue paper; candle; matches; pins;* 1 % *solution of potassium bichromate.*

APPARATUS: *Dissecting instruments and board; small glass dish.*

(*A*) Lay the eye on the board, as directed, with the *cornea*, or clear, front part of the eye, uppermost. Decide whether the specimen is a right or a left eye. The wider end of the cornea is always at the inner angle of the eyelids when the eyeball is in position.

Notice the transparent, circular area of the cornea, and observe that it is continuous with the grayish, opaque border of the *sclerotic*, or outer tunic of the eyeball. Trace this firm, fibrous, outer membrane over the sides and back of the

eye where it is covered with fat; note how it supports the eye in its spherical shape. It is much thicker behind than in front.

With forceps, gently raise the thin, delicate, transparent membrane, the *conjunctiva*, from the surface of the sclerotic. Remember that this membrane is continued as a lining for the eyelids. Note that the cornea forms the anterior sixth of the eyeball; it is almost circular in shape, and it projects forward like a watch glass from the sclerotic coat.

(*B*) Hold the eye firmly, and push the tip of the scalpel or knife straight through the *cornea* near the edge.

This membrane though transparent is very tough, so that force, discretion, and a sharp blade are required; this last should be held firmly, about 5 cms. (2 in.), from its point.

The clear liquid which escapes as the incision is made is the *aqueous humour*.

(*C*) Slightly elongate the cut, nip its upper edge with the forceps, and cut right round the margin of the cornea with the scissors, so that the cornea can be entirely removed.

(*D*) (1) Examine the dark, thin, contractile membrane now laid bare, it is called the *iris*. The central slit or opening, a little to the nasal side, is called the *pupil*; it allows the transmission of light; in man this slit is circular. The membrane derives its name "*iris*," a rainbow, from its various colours in different individuals. Press the eye very gently at the sides, the central aperture of the pupil will enlarge and show more distinctly.

NOTE.—The colour of the eyes depends upon the proportion of pigment cells present. There are several layers of black pigment cells on the posterior surface of the iris; if the substance of the iris itself contains no pigment the eyes are blue—a result of these dark posterior layers being seen through the unpigmented iris. If, however, there are dark pigmented granules in the substance of the iris itself the eyes are black, brown or grey, according to the proportion of pigment present.

(2) Raise the edge of the iris round the pupil with the forceps, and see that it is unattached to the structure beneath; observe its colour and markings.

NOTE.—The iris contains two sets of muscular fibres; one set is arranged in a circular manner and contracts the pupil, the other is arranged in a radiating manner and dilates the pupil. The iris acts like the diaphragm of a camera, cutting off the marginal rays of light which would interfere with distinct vision; it also takes part in what is known as accommodation (*page* 228), and protects the delicate retina by regulating the amount of light which enters the eye.

(3) Cut outward from one end of the aperture of the pupil to the margin of the iris; then remove the latter by cutting entirely round its outer margin.

Examine the appearance of the posterior surface of the iris, where the layers of pigment cells (*uvea*), are situated. These are a continuation forward of the pigment layer of the *retina*.

Notice also that the iris is a continuation of the thin, dark membrane, the *choroid*, which forms the second tunic of the eye and is firmly adherent to the sclerotic at the back. The inner surface of the choroid is attached to the *retina*, the third of the three tunics which invest the eye-ball. The choroid is connected to the circumference of the iris by what is known as the *ciliary body*.

NOTE.—The ciliary body is composed of the ciliary processes, the ciliary muscle, and numerous ridges arranged in a radial manner. This is known as *orbiculus ciliaris*. The ciliary processes are composed of a fringe of from 70 to 80 meridionally arranged, black, radiating plaits lying all round and immediately behind the iris, and are exposed upon its removal. It will be seen that they form a sort of pleated frill round the margin of the lens, being attached to its suspensory ligament, and that they establish a connection between the choroid and the retina.

(*E*) (1) The *crystalline lens* is enclosed in a transparent, highly elastic capsule, and is held in position by a sheet of delicate tissue fastened to its edges, called the *suspensory*

ligament. This ligament is a continuation of the *hyaloid membrane*, or outer coat of the *vitreous humour*, and has its origin at the same point as the ciliary processes. The lens lies immediately behind the pupil and in front of the vitreous body; the ciliary processes by which it is encircled slightly overlapping its margin.

NOTE.—The *hyaloid membrane* is united anteriorly to a fine but strong circular membrane called the *zonule of Zinn*. Where this joins the hyaloid membrane it is set in radiating folds into which fit the corresponding folds of the ciliary processes, so that the two (the ciliary processes and the zonule of Zinn) seem one membrane. The pressure exerted by this membrane flattens the front of the lens when the eye is at rest; when the tension of the membrane relaxes then the lens become more convex.

(2) Lay a piece of printed paper close to the eye to receive the lens, then make a quick, light cut across the capsule and very gently press the sides of the eye. The lens will slip out, sometimes very suddenly, and should be received on the piece of paper.

Look through the lens at the printed matter, and note the effect. Observe that the lens is bi-convex; the convexity being greater on the posterior than on the anterior side, possibly as a result of the pressure of the zonule of Zinn upon the front during those periods when the eye is at rest.

(3) Stick a sharp pin for a short distance into the edge of the lens and hold it at arms length between the eye and a lighted candle or match. Take a slip of transparent tissue paper, and endeavour to focus upon it the inverted image of the flame. Move the paper nearer to and then farther from the candle; how does this effect the position of the image relatively to the lens?

(4) Immerse the lens in a small glass dish containing a 1 % solution of potassium bichromate. Set it aside and study its structure at the end of a week, when the series of concentric lamina of which it is composed can be peeled off like the coats of an onion.

(*F*) (1) The transparent jelly-like mass upon which the lens rests is the *vitreous humour*. This fills the cavity behind the lens, and forms about four-fifths of the entire globe of the eye. It is composed of an albuminous jelly-like substance enclosed by the delicate *hyaloid* membrane.

Find the zonule of Zinn with its series of radial furrows. This splits into two layers, the thicker of which becomes the suspensory ligament of the lens.

(2) Carefully remove any foreign matter from the surface of the vitreous humour with scissors and forceps. The point of entrance of the *optic nerve* at the back of the eye can now be seen through the transparent medium, with the blood-vessels radiating from it. The external sheath of the optic nerve becomes continuous with the sclerotic coat as the nerve enters the eyeball. The number of fibres in the optic nerve is said to be upwards of 500,000.

(*G*) The *retina* will also be seen, lining the interior and posterior portion of the eyeball; it will probably be slightly wrinkled at this stage of the dissection, forming white ridges which radiate from the point of entrance of the optic nerve. It is upon the surface of this delicate nervous membrane that images of external objects are received; its structure is highly complex and consists of at least ten layers of certain nerve tissues.

Turn out the vitreous humour; then prove, by gently tearing it away from the choroid and following it to its origin, that the soft, delicate retina is a continuation of the optic nerve, of whose terminal fibres, deprived of their *neurilemma* (or encasing sheath), it is essentially composed, with the addition of nerve cells. The presence of these nerve cells shows that the optic nerve is an outgrowth of the brain, not an ordinary nerve, which consists of fibres and an *axon* only. (*See* "THE NERVOUS SYSTEM," III. (*H*) *pp.* 109, 110, 113.) The dark pigment layer of the retina will adhere to the choroid. Exactly in the centre of the posterior part of the retina is the "yellow spot" (the *macula lutea*).

Here the sense of vision is most perfect. The entrance of the optic nerve is slightly to the inner side of the yellow spot.

Note the lustre of the inner surface of the choroid, a peculiarity absent in the human eye; it gives the iridescent sheen seen in the eyes of certain animals; for example, the ox and the cat.

The *choroid coat* is a highly vascular membrane. Its black colour is due to a branching network of cells containing dark pigment.

(*J*) Turn the remaining tunics inside out; separate the choroid from the sclerotic and trace the blood-vessels which pass from the one to the other.

IV.—**Method II.** (*Adapted from* Dr. Edkins).

Materials: *Bullock's eye; slip of newspaper; tissue paper; candle; matches; pins;* 1 % *solution of potassium bichromate; water.*

Apparatus: *Dissecting instruments and board; flat glass dish.*

(*A*) (1) Remove the fat from a portion of the upper surface of the eye in order to expose the *sclerotic coat*; then make a pair of incisions along the surface from before, backwards, starting a few millimetres behind the junction of the *cornea* and sclerotic. There should be a distance of about 2 cms. ($\frac{3}{4}$ in.) between the two incisions where they start anteriorly, they should extend to about the same depth and must converge to one point posteriorly.

(2) Carefully peel up this triangular flap of the sclerotic coat from the apex towards the cornea and expose the *choroid*. Notice the dark underlining of the sclerotic, the *lamina fusca*. Observe that anteriorly the choroid is covered by a number of pale fibres passing forward to the corneo-sclerotic junction; these form the *ciliary muscle*.

(*B*) Carefully remove the exposed piece of the choroid, and note a pale membrane lying beneath; this is the *retina*.

(*C*) Place the eye in a flat glass dish of water, and make an incision right round through all the coats, in order to separate the posterior from the anterior half.

Examine the posterior half under water. Note the thin *retina* which floats away from the choroid.

Identify the *optic disc*, where the optic nerve enters the eye, and note the blood-vessels which radiate from this region.

The *vitreous humour* of jelly-like consistency will remain attached to the anterior half of the eye. Look through this at the crystalline lens. The radial folds of the choroid form the *ciliary processes* on each side of the lens.

The thick portion of the retina can be traced as far as these processes where it terminates with a wavy edge, the *ora serrata*.

(*D*) Now remove the vitreous humour and note that it adheres to the ciliary processes by its outer coat, the *hyaloid membrane*, while its more central portion appears adherent to the posterior surface of the lens. The posterior layer of the lens capsule is continuous with the hyaloid membrane.

If necessary, cut away the vitreous humour in order not to dislodge the lens.

(*E*) Make a radial incision from the edge of the sclerotic down to the edge of the lens. Carefully separate the iris and ciliary region from the lens.

The *suspensory ligament* will be seen passing from the ciliary body mainly towards the front surface of the lens. Carefully separate this from the lens, the suspensory ligament, which is continuous with the capsule of the lens, will then float away from the iris.

(*F*) Cut round the upper half of the cornea near its junction with the sclerotic. The *anterior chamber* will be exposed containing a clear fluid, the *aqueous humour*. Note the thickness of the cornea.

At the back of the anterior chamber is seen the black curtain of the *iris*, with its central aperture, the *pupil*.

(*G*) Notice that the fresh vitreous humour and lens, when placed in water, are not easily seen; they have almost the same refractive index as water.

Place a fresh lens aside; it will slowly become turbid and opaque.

Continue to examine the lens as in Method I. (*E*).

V.—Observations on Vision in the Human Eye.

MATERIALS: *Small mirror; knitting needles; book; black net veiling; pins; coin; pencil; piece of coarse string; Maxwell colour-top and discs, or "A.L." Spectrum colour-top; squares of red, black and white paper; glass prism; incandescent gas or electric lamp; water.*

APPARATUS: *Porcelain basin.*

(*A*) *Action of the Iris in Accommodation.*

(1) Hold a small mirror between the face and a bright light. Note the size of the pupils.

Turn quickly towards the darkest part of the room.

Watch the action of the iris in the mirror as shown by alteration in the size of the pupils.

(2) Direct a companion's attention from a distant to a near object; how does this affect the size of the pupils?

(3) Direct him to close one eye and to shade the open eye from the direct light. Observe the size of the pupil when the eye is shaded. Then remove the shade; the pupil will be seen to diminish in size.

From these experiments it may be inferred that the amount of light entering the eye is controlled by the iris.

NOTE.—The iris cuts off the more peripheral rays impinging on the cornea, otherwise the clearness of the image on the retina would be diminished. This is especially the case when viewing near objects, as here the angle of incidence of the

circumferential rays is greater. The dilatation and contraction of the pupil are reflex actions and therefore not instantaneous though rapid. A slow increase in the amount of light entering the eye causes a very slight amount of contraction, whereas a sudden flash causes a prolonged and marked contraction. This will probably be followed by a gradual dilatation of the pupil until it reaches its average diameter, 3 mm. ($\frac{1}{8}$ inch).

(*B*) *Power of Accommodation or Adaption of the Eyes for Distance.*

(1) Take two knitting needles (*a*) and (*b*), one in each hand. Close the left eye, and hold the needles one behind the other, directly in front of the right eye. Hold (*a*) at a distance of 20 cms. (8 ins.), move (*b*) to the furthest distance that your arm will allow.

Fix the sight upon (*a*); is (*b*) clear?

Fix the sight upon (*b*); how does this affect (*a*)?

(2) Place an open book about 25 cms. (10 ins.), from the eyes. Hold a piece of black net veiling at a distance of about 10 to 15 cms. (4 to 6 ins.) from the eyes.

Look through the net at the printed page; does the presence of the veil interfere with clear vision?

Look at the net, so that the threads are easily discerned; how does this affect your power to read the book?

Move the net nearer to the eyes; is fatigue caused by endeavouring to count the threads when so held?

(3) (*a*) Attach a piece of coarse string with a drawing pin to the back of your seat and carry it out in a direct line at right angles for a distance of $2\frac{1}{2}$ metres ($2\frac{3}{4}$ yards), fix it to some convenient object so that it forms a horizontal line.

(*b*) Take two pins, (1) and (2). Fix (2) on the string about 50 cms. (20 ins.) from the point of attachment on the seat. Take up a position close behind the string, your eyes on the same level as (2), and hold (1) in your hand close to the string about 20 cms. (8 ins.) from your eyes. Are both pins visible to you at the same time as single objects, or are their outlines blurred?

(*c*) Repeat the test four times, but at each repetition shift the position of (2) upon the string to the following distances from the point of attachment, 75 cms. (30 ins.), 1 metre (39½ ins.), 1½ metres (59 ins.), 2 metres (79 ins.). At which of these distances are the pins most distinctly visible at the same time as two single objects?

NOTE.—In order to see objects at varying distances the eye has the power of adapting itself in such a way as to form a clear image of these different objects on the retina. This adjustment is carried out by an alteration in the convexity of the lens brought about by the action of the ciliary muscles. The elastic lens is habitually compressed by the suspensory ligament; contraction of the ciliary muscles relaxes this ligament, diminishes this pressure, the lens becomes more convex, and the eye is adjusted for near vision. This modification in the shape of the lens is called "accommodation." In a well-formed eye the distance between the lens and the retina is such that when the eye is directed towards a distant object and the ciliary muscle is passive, the lens is held at the lowest limit of its refractive power, and a clear and distinct image is formed. Immediately the eye is turned from the distant object to a nearer one, the vision of the latter would be blurred, were it not that the ciliary muscle is at once brought into instinctive and involuntary activity. Well-formed eyes look at distant objects without fatigue, as no effort attends the action, but reading from small print can only be accomplished with effort even by the most perfect eyes, and therefore more or less fatigue is caused. The "power of accommodation" diminishes progressively with advancing age; the lens which is at its maxim of elasticity in childhood hardens and therefore expands less readily and freely however strong may be the effort of the ciliary muscles to cause convexity to increase; consequently artificial lenses, or spectacles, are employed to replace this diminished power of accommodation. The normal human eye has no limit to its range of distant vision, except such as are imposed by light or atmosphere, but for every eye there is a "near point," within which clear vision is impossible, and which recedes from the eye as age increases, because the lens loses its elasticity.

(4) *To illustrate the effect of the Refraction of Light upon the visual horizon.* Place a coin in an empty porcelain

basin. Arrange it on the upper ring of a retort stand, so that the coin is just not visible to the eye. Do not change the position of the eye, but pour water into the basin (*Fig.* 43).

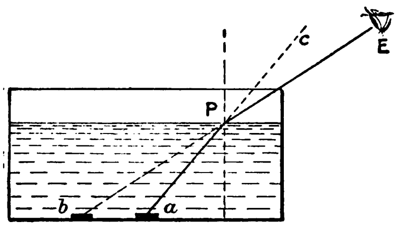

FIG. 43.

The ray of light, *aPc*, is refracted at *P*, in the direction *PE*, and the observer imagines the coin to be in the direction *EPb*, *i.e.*, at *b*.

Observe the result brought about by the fact that the rays of light are *refracted* or bent as they pass *obliquely* from the air into the water.

NOTE.—This experiment demonstrates the fact that the effect of refraction is to widen our horizon. More especially is this the case when the density of the atmosphere is increased; objects usually below the horizon then become visible; *e.g.*, the Isle of Wight will be seen from Bournemouth or Bognor, or the coast of France from Dover or Hastings. The "mirage" affords another illustration of refraction which results from the unequal density of the different layers of the air, when they are expanded by contact with heated soil. Bodies immersed in a medium more highly refracting than air appear nearer the surface of this medium, and *vice versa*.

(5) *The Near Point.* Hold a needle about 2 feet from the eye and gradually bring it nearer. Note that for a certain distance it is possible to obtain a clear image. Finally, in spite of effort, the image becomes blurred.

NOTE.—The least distance at which one obtains a clear vision of the needle corresponds to the *near point* of accommodation, or *punctum proximum*. This is generally about 12 cms. (4¾ ins.), but varies considerably in individuals. The range of accom-

modation lies between the near point, or ***punctum proximum***, and the far point, or ***punctum remotum***. At ten years of age the near point averages 8 cms. (3 ins.) from the eye, at twenty it has increased to 11 cms. (4½ ins.), at forty-five it is usually 25 cms. (10 ins.), at the age of sixty the distance amounts to 90 cms. (1 yard), at seventy-five years of age the power of accommodation is usually lost.

(*C*) *The Blind Spot.*

(1) Close the left eye; hold this book horizontally; direct the right eye to the cross, and move the page to and fro until the point is found at which the dark circle is no longer seen.

(2) Repeat the test with a florin laid on the table; can this be so placed as to disappear entirely?

NOTE.—The sensitive portion of the retina is absent at the point where the optic nerve enters the eyeball, consequently there is no perception of light, hence the point of entrance is known as the "blind spot."

(*D*) *Binocular Vision.*

(1) Hold a pencil vertically in a line with the nose about a foot in front of the eyes. Look at a distant object. How does the pencil appear?

(*a*) With the right eye closed.

(*b*) With the left eye closed.

(*c*) With both eyes open.

(2) Make observations upon a companion, who should be seated upon a chair placed opposite to your own.

Hold a pencil or knitting needle vertically about 1 metre (1 yd. 3 ins.) from his eyes and move it slowly (*a*) upwards, (*b*) downwards, (*c*) diagonally, (*d*) laterally.

Observe the convergence of the eyes, that is the continuous fixation with both eyes upon the object, in whatever plane it is held.

NOTE.—The axes of the eyes are parallel when looking at a distant object, but they must converge to look at a near object.

This is a condition constantly occurring in binocular vision, the intention of which is to bring the "yellow spot" (that part of the retina in both eyes where vision is most distinct) to bear on the same object. This is accomplished by the simultaneous contraction of both the internal recti muscles. Where the axes do not cross at the object to which the eyes are directed the result is "squinting." The squint is *convergent* when one eye turns more inward than the other; it is *divergent* when one eye turns more outward; but many varieties of *strabismus* (squint) exist.

It is of great importance to give children who squint suitable eye exercises, or other remedial treatment, as early as possible. Whether the cause be muscular or nervous, an eye which habitually squints will probably become functionally useless, and possibly blind, in later life.

(*E*) *Visual Judgments.*

(1) Do the horizontal lines of *Fig.* 44 appear to be of the same length? Measure them.

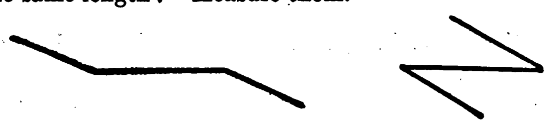

FIG. 44.

(2) Hold *Fig.* 47 at arm's length. Of what does it remind you?

Bring it slowly nearer the eyes. What do the lines now suggest?

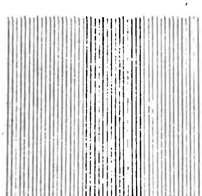

FIG. 45.

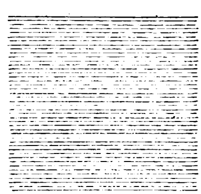

FIG. 46.

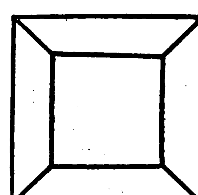

FIG. 47.

(3) Are the two squares, *Figs.* 45 and 46, the same size? To what cause may any misconception on the point be attributed?

(4) Draw—(*a*) A horizontal line 5 cms. (2 ins.) long.
(*b*) A perpendicular line 5 cms. long.
(*c*) A diagonal line of the same length.

Do all three lines appear of equal length?

(5) Make five black dots in line with, and equidistant from, each other, mark them underneath, (*a*), (*b*), (*c*), (*d*), (*e*).

Fill the space between (*b*) and (*c*) with arrow-heads pointing towards each other.

Fill the similar space between (*d*) and (*e*) with equidistant dots.

Which appear the furthest apart of the five figures?

NOTE.—These illustrations show how unreliable are sensations, visual ones especially, unless reviewed in the light of experience or qualified by judgment. Few things are seen as they really are, and judgment must be constantly employed to interpret the crude impressions received by the senses.

(*F*) *Retention of Vision* (or persistence of impressions on the retina).

(1) Fray the end of a piece of coarse string; set it alight, and whirl it round with increasing rapidity. Are the sensations those of an intermittent or of a continuous light?

(2) Cover one quarter of the disc of a Maxwell Colour-Top, or an "A.L." Spectrum Colour-Top, with red paper and the remainder with orange. Rotate the spindle rapidly. What colour-impression is received by the eyes?

(3) Look steadily at a small square of white paper laid upon a black ground, then slip a piece of paper (white) over the whole and notice what is called the "negative after-image."

(4) Look steadily at a square piece of bright-red paper laid on a black ground, and then slip a piece of white paper over the two. What colour is the after-image in this case?

Repeat (4), using other squares of various coloured papers provided for the purpose.

(5) Look at a strong light, as an incandescent gas or electric lamp, for about half a minute. This is the length of time usually necessary in order to get a well-marked "after-image." If the eyes be then directed to a white surface the after-image will be "negative," if to a dark surface it will be "positive." Which of the two, the positive or negative after-image, most resembles the original object in the distribution of light, shade and colour?

Observe the colour of the "after-images" in this experiment, and note the gradual change in colour which they show. If the after-images become faint, blink the eyes several times rapidly and they will become more marked.

Test this statement especially in connection with the negative after-image seen on the white surface. The image will become converted during the shutting of the eyes into a positive after-image.

NOTE.—The duration of the sensation produced by a light stimulus on the retina is always longer than that of the impression which produces it, because however brief the cause, the effect on the retina always lasts about one-eighth of a second. These after-sensations are called "*after-images*" and are of two kinds, *positive* and *negative*. The "positive" resembles the original image in distribution of light, shade and colour; in the "negative" the dark and light parts are reversed, and the coloured parts show their *complementary colours*. A "complementary" colour is one which, if united to that of the object, would form white. For a *red* object the image would be *green*, if an object be *violet*, the image will be *yellow*.

(*G*) *Irradiation.*

(1) Take the papers used in (*F*) (3) and observe which looks larger, the white square on the black ground, or the black square on the white ground.

NOTE.—*Irradiation* is due to the fact that the stimulus is so strong that the disturbance of nerve endings extends beyond the actual area of the retina upon which light rays fall. As a result of this phenomenon, the white square on the black ground looks the larger, in consequence of the kind of halo which appears round images of small white objects. Irradi-

ation increases with the intensity and duration of the light stimulus, and is independent of the length of the light ray. It is considered by some authorities that the unequal refractive powers of the cornea, lens and vitreous humour protect the eye against the effect of what is known as *chromatic aberration*. Chromatic aberration is the unequal bending of the different coloured rays of which a ray of "white light" is composed when passing through a prism or a lens. The phenomenon occurs in all cases where the eye has time to adapt itself to the necessary different distances of sight, or when the object is at the required focal distance from the retina. Interference with either of these conditions, as in this experiment, results in what is known as "irradiation"; of which, as has been pointed out, a primary cause is the decomposition of light into its elementary colours. This occurs when light passes through an ordinary convex lens, such as the crystalline lens of the eye.

(2) *To observe the Decomposition of White Light.*

(*a*) Turn the back to the window, or to an electric light. Hold a sheet of thick white paper at arm's length, then manipulate a glass prism so as to project the spectrum on the paper; or, if a beam of sunshine be allowed to enter a moderately lighted room, through a small aperture (preferably a small slit), move the prism in such a way as to cause patches of rainbow colours to appear on the ceiling and walls.

(*b*) Turn towards the light, and looking through the prism when held at different angles, observe the effects upon the colour, size and form of the contents of the room.

(3) *To Demonstrate the Phenomena of the Spectrum.*

(*a*) Arrange the discs on a Colour-top so that equal portions of red, green and blue are exposed. Rotate rapidly and observe the result obtained.

(*b*) Add to these discs a small black and a small white one, arranged as in *Fig.* 48, and again rotate the top. Observe that although pigmentary colours (because of their inevitable defects) cannot repro-

duce pure spectrum colours, yet the combination in (*a*) results in a *neutral gray*, similar to white in shade, and a similar effect is gained in (*b*), for purposes of comparison, by the employment of the black and white discs.

NOTE.—These experiments serve to illustrate, though imperfectly, the production of white light by the spectrum colours. It is impossible in the present conditions of chemistry to prepare artificial colours which shall reproduce exactly those of decomposed light, consequently the combination will result in a neutral tint instead of white; but the principle will be demonstrated with sufficient clearness to illustrate the point.

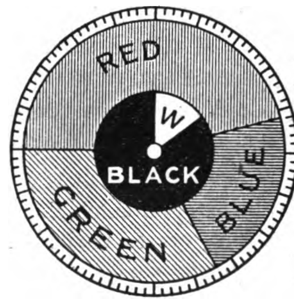

FIG. 48.

(*II*) *To test Acuteness of Vision.*

(1) This is measured by means of letters sized to certain definite standards, and displayed on a sheet of cardboard, which is suspended in a good light in the direct line of vision, at a distance of 6 metres (20 ft.) from the individual whose vision is to be tested. Reproduce the relative position of the test types and their subject by supporting this book about 2 metres (6 ft.) from the floor, and displaying the specimen letters on *page* 238 in a good light.

(2) Stand with the back to the light at a distance of 6 metres (20 ft.) from the book.

(3) Hold a piece of cardboard in front of the right eye, being careful not to press it upon the eyeball. Then read the letters in the line marked No. 7.

Write down those read with ease, and compare your list with the series of letters on the page. Which, if any, are indistinct or illegible?

No. 7. 6 *metres* (20 *feet*).

D Z R Q U V

(4) Repeat (3) with the right eye, holding the opaque cover before the left eye.

If all the letters in this line are read with ease by both eyes, vision is normal, and would be technically described as $V\frac{6}{6}$; *i.e.* the line marked No. 7 can be read by each eye at a distance of 6 metres.

(5) Stand at a distance of 9 metres (30 feet), from the book, and, employing the same method, test the power of each eye to read all the letters in the line marked No. 6. Should one eye prove unequal to the test, and be able only

No. 6. 9 *metres* (30 *feet*).

G K M L A

to distinguish the letters clearly at a distance of 6 metres (20 feet), instead of at 9 metres (30 feet), the acuteness of vision would be expressed as follows:—$V\frac{6}{9}$; *i.e.*, some defect exists in the acuteness of vision, and one eye can only read at a distance of 6 metres (20 feet) what a normal eye can read at 9 metres (30 ft.).

(*J*) *Test for Near Vision, or Myopia.*

(1) Hold the book in a good light and note which of the following paragraphs can be read at the distances indicated without effort to the eyes.

No. 9. (2 *feet*.)

Dick felt very, very lonely, for though there were many people walking about, he did not know any one. No one looked at him, no one spoke to him, and it made him sad to see dirt everywhere, but no gold in the streets. Weary, and sick at heart, and having nowhere to go, he sat down in the corner of a doorway, and cried himself to sleep.

No. 10. (2½ *feet.*)

When Elsie awoke next morning, the sun was shining into the bedroom. She did not mind the sun now, for the air was cool, and fresh, and sweet, not like the smoky air of the big town. Elsie and her cousin dressed themselves, and when they were ready, they went down stairs. Their Aunt was busy getting breakfast ready, and baby was playing on the rug.

No. 11. (3 *feet.*)

With the help of their dogs, they gather all their sheep together in a place called a Sheep-pen. The lambs are left outside, and bleat very sadly. They think that they have lost their mothers. The sheep are washed one by one, and then the wool is cut off with big shears.

No. 12. (4 *feet.*)

Robin Hood and his men lived a healthy and free life under the greenwood tree. When they wanted meat, they shot the deer and the boar, and when they wanted other things, they took them from the rich merchants, who often had to pass through the forest.

No. 13. (5 *feet.*)

Our home was quite safe while the farmer waited for others to do his work, but depend upon it, the corn will be quickly cut, now that he has made up his mind to cut it himself.

No. 14. (6 *feet.*)

I carried the little child to its home, and he patted me, and loved me so much.

No. 15. (8 *feet.*)

The bird flew a long way, and at last it came over the rough sea.

No. 16. (12 *feet.*)

Next his skin he wore a shirt made of hair.

No. 17. (16 *feet.*)

The merry lark came at last.

(2) Read the paragraph marked No. 11; measure the distance from the eyes at which this can be done with ease. Is it more or less than 1 metre (39 inches)? (This is the normal distance at which the eyes should easily read the words in a good light.)

NOTE.—The degree of *Myopia* (short-sightedness) present is gauged by noting the greatest distance at which each paragraph *is* read with ease, and by comparing this with the normal distances at which it *should* be read. For instance, if a type which is easily read at a distance of one metre by a normal eye is only read at a distance of 50 cms., one half of the normal distance, the subject of the test has 2 degrees of myopia.

(*K*) *Test for Astigmatism.*

Hang up an Astigmatic Chart, and test each eye under similar conditions of lighting and in the same way as direeted in (*H*). *Fig.* 49 illustrates the type of chart used for this purpose.

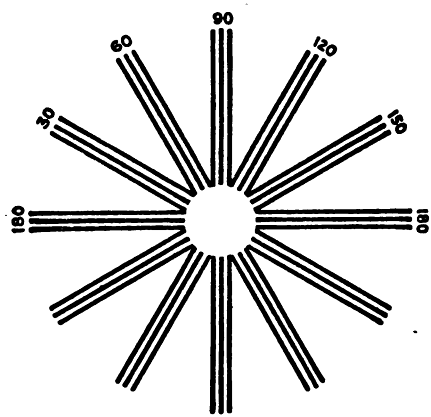

FIG. 49.

Do all the lines appear equally distinct and black to each eye? Notice if any seem blurred or grey, and in which meridian they occur, the vertical or the horizontal.

NOTE.—The *Long-sighted or Hypermetropic* eye is too short from front to back along the axis of vision. Parallel rays do not meet exactly on the retina, but being prolonged behind it, cause a blurred image. The *Short-sighted or Myopic* eye is too long from front to back. Rays from a distant object focus in front of the retina; and the result is again a blurred image.

Astigmatism is usually due to an abnormal shape of the cornea, of which the vertical or horizontal curves are greater the one than the other, so that the eye when at rest does not focus parallel rays of light upon the same spot. It is a very common imperfection and appears in at least seven different forms. The minor degrees do not as a rule cause any inconvenience, the major are responsible for as much mental as physical suffering; inability to distinguish figures in each meridian on the face of a clock or accurately to read musical notation being often mistaken for wilfulness, stupidity or inattention in children. The formula used in testing the acuteness of direct vision is as follows:—$V = \frac{d}{D}$; *V.* stands for vision; *d.* stands for the distance of the subject from the test type; *D.* the distance from which it should be read. It is a rare occurrence for both eyes to possess quite normal vision, and the result of even slight defects are so far-reaching that attention cannot be directed to their existence too early.

Debility, dyspepsia, headaches and other ailments are constantly traced to quite small ocular defects. It must be also borne in mind that the *myopic* or *astigmatic* child is at a great disadvantage, owing to his restricted range of vision and to the imperfect impressions of form and detail which he receives.

No rough or unskilled examination of the eyes, such as is included, for the sake of illustration in (*H*), (*J*), and (*K*), is trustworthy; it cannot be too strongly impressed upon young people and their parents, that the skill of an oculist is necessary to secure that suitable lenses are supplied to correct any defects which exist.

It is also often insufficiently realized that the eye of a little child is immature; not well adapted for distant vision, and entirely unfit for near work. During this period of life the ocular tissues are soft and delicate; if the eye be constantly directed to near objects the coats of the eyeball become pressed out of shape owing to the pressure of the tense muscles, while the coincident ciliary congestion causes an unhealthy condition of the tissues, and thus refractive error is accentuated or developed. The process of complete ocular development is irregular and prolonged, and varies much in individuals.

In addition to the exercise of intelligent care during school hours, children should be warned against reading or working by flickering candles, lamps, gas jets or firelight, and from otherwise using their eyes for close application under bad conditions of light. Children under seven years of age should be taught to read from well-printed wall-sheets; the lower classes in a school should use books printed on unglazed paper in type easily legible at a distance of 80 cms. (about 2½ ft.), while the size of type called "pica" (*see* (3), *page* 244) is the smallest type allowable for upper class text books. Even this type should be preferably "leaded" (*i.e.*, with the lines well separated), which permits of reading with ease at a greater distance from the eyes (an important point in childhood), than when it is "solid" or "thin leaded."

(L) *Illustrations of Types in Common Use.*

The following specimen passage illustrates varieties of type-leading.

(1) *Pearl. Solid.*

"For a machine to work at its greatest efficiency it must be in perfect order. The human eye takes many years to reach its full development; it therefore requires care during growth. A healthy eye is clear and bright; there is no soreness of the eyelids or other discomforts, such as fatigue or headache.

Pearl. Thin leaded.

"For a machine to work at its greatest efficiency it must be in perfect order. The human eye takes many years to reach its full development; it therefore requires care during growth. A healthy eye is clear and bright; there is no soreness of the eyelids or other discomforts, such as fatigue or headache."

Pearl. Thick leaded.

"For a machine to work at its greatest efficiency it must be in perfect order. The human eye takes many years to reach its full development; it therefore requires care during growth. A healthy eye is clear and bright; there is no soreness of the eyelids or other discomforts, such as fatigue or headache."

(2) *Long Primer. Solid.*

"For a machine to work at its greatest efficiency it must be in perfect order. The human eye takes many years to reach its full development; it therefore requires care during growth. A healthy eye is clear and bright; there is no soreness of the eyelids or other discomforts, such as fatigue or headache."

Long Primer. Thin leaded.

"For a machine to work at its greatest efficiency it must be in perfect order. The human eye takes many years to reach its full development; it therefore requires care during growth. A healthy eye is clear and bright; there is no soreness of the eyelids or other discomforts, such as fatigue or headache."

Long Primer. Thick leaded.

"For a machine to work at its greatest efficiency it must be in perfect order. The human eye takes many years to reach its full development; it therefore requires care during growth. A healthy eye is clear and bright; there is no soreness of the eyelids or other discomforts, such as fatigue or headache."

(3) *Pica. Solid.*

"For a machine to work at its greatest efficiency it must be in perfect order. The human eye takes many years to reach its full development; it therefore requires care during growth. A healthy eye is clear and bright; there is no soreness of the eyelids or other discomforts, such as fatigue or headache."

Pica. Thin leaded.

"For a machine to work at its greatest efficiency it must be in perfect order. The human eye takes many years to reach its full development; it therefore requires care during growth. A healthy eye is clear and bright; there is no soreness of the eyelids or other discomforts, such as fatigue or headache."

Pica. Thick leaded.

"For a machine to work at its greatest efficiency it must be in perfect order. The human eye takes many years to reach its full development; it therefore requires care during growth. A healthy eye is clear and bright: there is no soreness of the eyelids or other discomforts, such as fatigue or headache."

(*M*) *A rough Test by which to Gauge the Size of Print.*

Take a piece of white card, and carefully cut a small opening to measure exactly 1 sq. centimetre. Place this over the print to be tested, so that the lower edge of the opening exactly covers the upper edge of one line of print.

If more than two lines of print appear in the opening, the print is too small for general use by children.

(*N*) *Examination of Lenses used for Spectacles.*

Materials: *Convex and concave lenses; glass prisms.*

(1) Examine a *convex* lens; which is the thicker part?

(2) What is the effect upon the eye when this lens is placed between it and a sheet of printed matter?

(3) Examine a *concave* lens as in (1).

(4) Is the effect upon the eye the same as that experienced in (2) when a similar experiment is tried?

(5) Test the power to see distant objects clearly with either lens.

Note.—To explain the action of lenses (spectacles) and the assistance they can render to the eye when properly selected and adjusted, repeat (*B*) (4) (*page* 230), which illustrates the effect of refraction on rays of light passing obliquely from one medium to another, and connect this with a diagram placed on the blackboard to illustrate the refractive power of a

prism. Impress on the pupils that the amount to which the rays of light will be deflected depends upon the shape and material of the prism, and on the angle at which the rays of light impinge upon its surface.

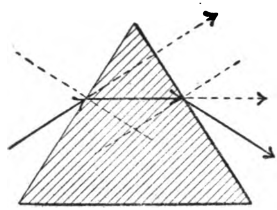

Fig. 50.

It was Willebrord Snell, a Dutch Mathematician and Professor of Mathematics at Leyden (1581—1626), who discovered the laws which govern the refraction of light, by acquaintance with which the path of the rays in a prism can be easily determined. This knowledge is applied when it is desired to make good what is defective in the human eye by means of lenses (spectacles). Lenses are defined as "transparent media, which from the curvature of their surfaces have the property of causing the luminous rays which traverse them either to converge or to diverge." According to their curvature they are either spherical, cylindrical, elliptical or parabolic. Lenses may be described as resembling two prisms in contact at their apices or at their bases. With young students a better comprehension of the service rendered to imperfect eyes by suitable lenses often results if the following diagrams be studied in conjunction with two glass prisms, or even with triangles cut from paper to represent prisms; (*c*) (*d*) and (*e*) illustrate forms of lenses in general use for spectacles.

(*a*) Double convex.

(*b*) Double concave.

(*c*) Plano-convex.

(*d*) Plano-concave.

(*e*) Concave-convex.

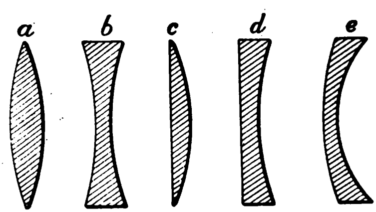

Fig 51.

"The term 'refraction of the eye' is used for the refracting power of the eye in repose, without any exertion of the accommodation muscle. Refraction is normal, that is, the axis of the eye is of normal length, when rays of light which come from infinite distance are focussed exactly upon the retina itself. In such a case we say that the refraction of the eye is *emmetropic* (from *emmetros*, 'of the right measure,' and *ops*, 'the eye').

"Again, the axis of the eye may be too short, so that rays coming from infinite distance are focussed at a point behind the retina; this refraction is termed *hypermetropic* ('going beyond the measure') or *hyperopic*. This hypermetropia must in no way be confounded with the long sight often noticed in old age, when elderly persons only see things clearly which are at a distance, a defect caused by weakness of accommodation; this is called *presbyopia* (from *presbus*, 'old,' and *ops*, 'the eye').

"Lastly, the axis of the eye may be too long, so that rays from infinite distance are focussed in front of the retina. This kind of refraction is called short-sightedness or *myopia* (from *muein*, 'to blink,' and *ops*, 'the eye'), because most short-sighted people nearly close their eyelids when they try to look at any distant object."—(Cohn.)

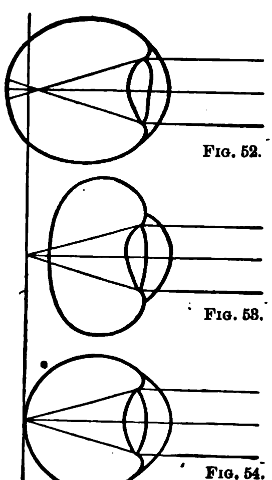

FIG. 52.

Fig. 52.—*Myopic Eye;* in which the rays of light are brought to a focus in *front* of the retina, and thus objects at a distance are either not seen at all, or seen only indistinctly.

FIG. 53.

Fig. 53.—*Hypermetropic Eye;* in which the rays of light are brought to a focus beyond the retina, and thus the eye receives only an imperfect image of near objects.

FIG. 54.

Fig. 54—*Emmetropic* or *Normal Eye;* in which the rays of light are brought to a focus on the retina.

When a *convex* lens is used, the eye must adjust itself as if looking at remote objects; the lens causes the rays of light to converge or bend *towards* the short *axis*, that is, in a convex lens, *towards* its thickest part; it acts as a magnifier and gives the impression that the object is magnified, *e.g.*, four words in a page of print seen through a convex lens appear to be at a less distance from the eye than the surrounding matter. A concave lens also bends the rays of light *towards* its thickest part, in this case the edges, but *away from* the axis; thus it causes rays of light to diverge. The eye must adjust itself as if for near vision, and distant objects will appear nearer, but at the same time smaller.

The results when lenses are employed to correct refractive defects of vision are illustrated in *Figs*. 55, 56.

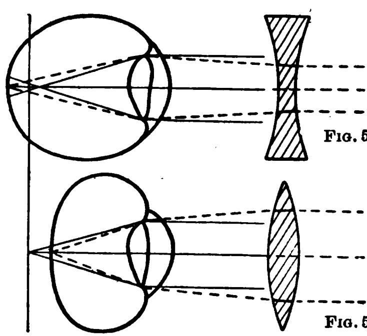

FIG. 55

FIG. 56

Fig. 55.—Showing the action of a *concave* lens, which, by causing the rays of light to *diverge*, brings them to a focus on the retina, and so corrects defects due to near-sighted or myopic vision.

Fig. 56.—Showing the action of a *convex* lens, which, by causing the rays of light to *converge*, brings them to a focus *on* instead of *behind* the retina, and so corrects defects due to long-sighted or hypermetropic vision.

VI.—The Colour Sense.

MATERIALS: *Sheet of pale gray paper; 3 large "test" skeins; confusion colours; Thomson's Colour Stick.*

Spread the sheet of pale gray paper over the table, in order to afford a good ground for the following experiments.

(*A*) *Holmgren's Test*.

Take the three large "test" skeins of yarn, and select from among the mass of "confusion colours" supplied tints identical with those in each of the test skeins. Compare results with those arrived at by your companions.

(*B*) *Thomson's Stick Test.*

Take the "test" skein, and match it in colour from the yarns arranged on the stick.

How many times is the colour of the test skein repeated?

NOTE.—The "colour sense" is the power possessed by the retina of perceiving the colours which result from the different refrangibilities of the light rays, as they pass through the cornea, lens and vitreous humour. *Achromatopsy*, or colour blindness, is a curious defect of vision which shows itself in the inability of a person to distinguish between certain colours, which to persons not so affected, are quite dissimilar. Four forms of colour-blindness have been described; *red*, *green*, *violet*, or *total* colour-blindness, of which the first is by far the most common. Partially colour-blind persons are those who are blind to two particular groups of hues which are complementary.

In Holmgren's Test the subject is given three large test skeins dyed with standard test colours in the following order; (1) bright pure green, (2) purplish-pink, (3) bright red; while the "confusion colours" consist of a tangled mass of reds, oranges, yellows, greens of every shade, violets, pinks, browns and grays. The green skein must always be given first, for if only the true greens are chosen as matches to it normal vision is assured and no further test is necessary. If false matches are made with green, it is important to ascertain the portion of the colour spectrum with regard to which complete blindness exists.

Dr. William Thomson's test is also given here as it has been used for testing colour-blindness among railway employees. In this a pure light green is used as the test. Alternate skeins of this colour (green) are arranged on a long stick with "confusion colours" between. The whole series is numbered from one to twenty; the odd numbers being all of this one shade of green, the even numbers being "confusion colours."

In the first test, a colour-blind subject will confuse the pinks, reds, browns, grays and greens. In the second, if normal, he should name none but odd numbers. As a rule, if gray, brownish-grays, yellow, orange or pink is confused with *green*, there is *total* colour-blindness; if blue or violet is matched with *purple*, a subject is *red* blind, and will select dark green or brown as identical with *bright red*,

If gray or green is matched with purple a subject is *green* blind, and light greens or browns will be chosen as similar to bright red, a condition difficult to distinguish from red blindness. When red and orange are confused with purple a subject is *violet* blind; an exceedingly rare phenomenon.

"The most interesting fact about colour-blindness is that it appears to be entirely a matter of formation. It occurs among all nationalities, in proportions ranging from about 2 per cent of the more wealthy to about 4 per cent. of the labouring classes of males, and in about one-tenth of that proportion of females; and it is probable that a certain incompleteness or indefiniteness of colour-vision may be somewhat more widely diffused. Most ladies could mention others among their acquaintances in whom a sense of colour harmonies, at least, does not habitually display itself in their attire. Many attempts have been made to correct colour-blindness by various expedients, such as by looking through media coloured by 'fuchsine,' or to improve the deficient sense by training, but none of them has ever been rewarded by the slightest measure of success. A person who is born colour-blind will remain so; and, in some positions, as when it becomes his duty to recognise the colour of signals, his defect may be a source of serious disaster. In military service, when it may often be important to recognise the colours of uniforms seen from a distance, defective colour-vision is perhaps as dangerous as in almost any other position."—("*Sight and Hearing in Childhood.*" CARTER AND CHEATLE.)

XIII.—SPECIAL SENSE ORGANS (*contd.*).

(B) THE EAR.

External Observations. Study of a model of the human ear. Dissection of a rabbit's ear. Tests for hearing. Auditory sensations. Illustrations on sound.

I.—Observations on the External Ear.

MATERIALS: *A good model of the ear.*

(*A*) Feel the substance of the *pinna auricle,* or outer ear. It is formed of elastic cartilage covered with skin, and serves to collect the vibrations of the air by which sound is produced.

Note the variations in shape and size on different people, which make this feature peculiar to each individual.

(*B*) Identify the following details of the formation of the pinna upon the ear of a companion with the help of the diagram and a good model (*Fig.* 57).

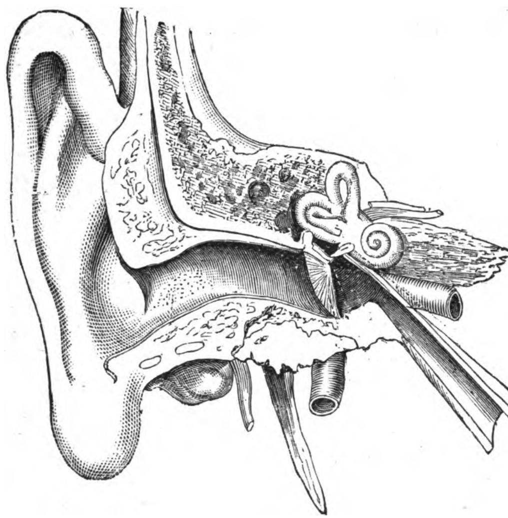

FIG. 57.

(1) The *helix*, or external prominent rim of the auricle.

(2) The *fossa* of the helix; a narrow curved depression between (1) and (3).

(3) The *antihelix* (or *anthelix*); a curved prominence parallel with, and in front of, the helix.

(4) The *fossa* of the antihelix; a triangular depression, enclosed by (3).

(5) The *tragus*; a small pointed eminence, which projects backwards over the meatus (9); so called from a tuft of hair on its under surface, resembling a goat's beard.

(6) The *antitragus*; a small tubercle opposite the tragus.

(7) The *concha*; the central capacious cavity, partially divided into two parts by the commencement of the helix.

(8) The *lobule*; composed of tough tissue which may be free or attached to the head.

(9) The *meatus*, or external auditory canal, which leads inwards by a funnel-shaped opening, and conducts vibrations of the air to the *tympanum* or middle ear. It is about 2·5 cms. (1-in.) long.

The *hairs*, always present (but only occasionally noticeable), at its mouth; these help to exclude insects and other foreign bodies. The *bitter wax* also present in the meatus is the secretion of numerous glands. It serves to entangle not insects only, but bacteria.

NOTE.—The canal is shaped in such a way as to facilitate the passage outward of this wax, which in normal ears requires no artificial method of removal, such as the introduction of pins, sponges, ear-spoons, or other undesirable aids to cleanliness.

II.—**Observations on the Middle Ear** (to be carried out on a good papier maché model).

(*A*) Notice (1) That this portion of the auditory apparatus, termed the middle ear or *tympanic cavity*, is deeply embedded in the substance of the petrous part of the temporal bone.

(2) That the small cavity of which the middle ear consists is separated from the external auditory canal by the *tympanum* or *drum*, and the ring of bone into which this thin, semi-transparent membrane is inserted. The middle ear has also two small openings on its inner wall, the "oval window," or *fenestra ovalis*, and the "round window," or *fenestra rotunda*, both closed by membranes, which shut it off from the *vestibule* and *cochlea* of the inner ear, or *labyrinth*.

(3) That the cavity is filled with air which reaches it through the *Eustachian tube*, a channel connecting the floor of the middle ear cavity with the naso-pharynx (or that part of the pharynx which is behind and above the soft palate); the orifice of the tube is above, and concealed from view by, the soft palate. This tube is about 4 cms. ($1\frac{3}{4}$-in.) long, and is formed of bone, cartilage and fibrous tissue. The air pressure in the middle ear is kept the same as that of

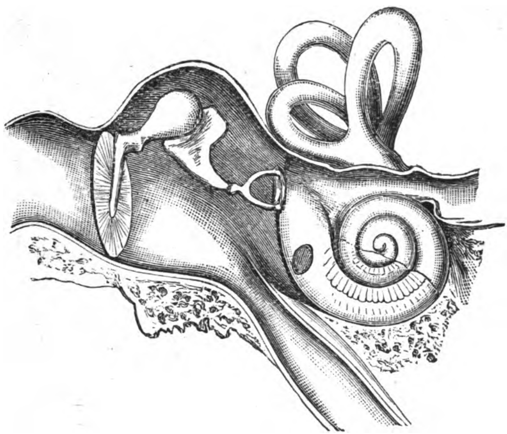

FIG. 58.

the atmosphere by means of the Eustachian tube; though, except in the act of swallowing, when it is opened by the action of the *tensor palate muscles*, the mouth of the tube is closed (*Fig.* 58).

(*B*) (1) Notice the chain of small bones, the *auditory ossicles*, which stretches across the cavity of the tympanum, connecting the two sides. Examine these bones, and trace in them the fancied resemblances to the objects from which they derive their names.

(*a*) The hammer, or *malleus*, which is attached to the drum of the ear.

(*b*) The anvil, or *incus*, connected by delicate articulations to (*a*) and (*c*).

(*c*) The stirrup, or *stapes*, which is attached to the oval window.

Observe the manner in which the incus is jointed to the malleus and the stapes, and the position of these bones with respect to the walls of the middle ear. The arrangement is such that vibrations are transmitted from the drum, along the chain of bones, through the membrane of the "oval window," to the fluid contained in the internal ear—that part which is situated on the other side of the oval window.

(2) (*a*) In order to demonstrate the connection of the throat with the middle ear by means of the Eustachian tube, shut the mouth and pinch the nose tightly, then force air down the nose. Notice the sensation caused by the impact of the air, as it is forced up the Eustachian tube against the drum.

The "clicking" sound is caused by the movements of the auditory ossicles and the membranes with which they are in contact.

NOTE.—In sneezing, which is a violent expiration, some air is often forced thus through the Eustachian tube into the middle ear. The "bulged out" feeling in the ears and the partial deafness experienced are at once relieved by swallowing; this opens the Eustachian tube, and re-establishes equality of pressure.

(*b*) Ask a companion to recite some verses in a clear voice. During the recitation shut your own mouth and pinch the nose as in (*a*). Then endeavour to take a deep inspiration.

Is the voice heard distinctly throughout the experiment or does the increased pressure on the inner side of the drum, during the forced inspiration, interfere with its power to transmit the vibrations, caused by the waves of sound from the speaker's mouth?

NOTE.—The whole middle ear is lined with mucous membrane, continuous with that which lines the nose and throat. Any inflammation, such as a severe cold, which causes swelling of this mucous membrane, frequently leads to temporary deafness, owing to the blockage of the Eustachian tubes, so that air cannot pass readily to and fro between the throat and the middle ear. The pressure of the external atmosphere upon the drum is then no longer equalized by the air pressure on the inner side of the tympanic membrane; this latter becomes tense, vibration is impossible, and consequently no sound waves can be communicated to the middle or inner ears. The feeling of uncomfortable tightness in the ears with which divers are familiar when engaged in their occupation is also the result of increased external pressure, which compresses the air in the middle ear cavity. The action of swallowing, by opening the orifice of the Eustachian tube, affords relief by equalizing the air pressure.

When the drum is exposed to sudden, violent, external pressure, as from the firing of a large gun, risk of rupturing the tympanic membrane is averted by holding the mouth open, and thus equalizing the pressure on both sides of the tympanum. The mechanical action of the auditory ossicles will need careful explanation as it cannot be observed in a rigid model; neither can the beautiful mechanism of the tiny muscles, attached respectively to the handle of the malleus and to the stapes, be reproduced. The function of these muscles is to regulate the transmission of violent impulses which might produce excessive vibrations of these membranes. The one tightens the tympanum, the other restricts the movements of the *fenestra ovalis*.

The minute size and exquisite delicacy of the parts of the middle and internal ear must be emphasized; and, if possible, actual specimens of the auditory ossicles and cochlea should be exhibited, otherwise very inaccurate notions may be formed from even the best models.

III.—Observations on the Internal Ear (to be made on a good model).

Observe that the internal ear consists actually of a closed sac in a bony cavity, the petrous part of the temporal bone. It is called the *labyrinth*, from the complexity of its shape; and consists of two parts; the *osseous labyrinth*, a series of cavities chiselled out of the substance of the

petrous bone; and the *membranous labyrinth*, the latter being contained within the former, and not to be distinguished from it in a model. The osseous labyrinth is divided practically into three parts, technically known as the *vestibule*, the *semi-circular canals*, and the *cochlea*.

(1) The *vestibule* is situated in the posterior portion of the sac; it is the common central cavity of communication between the parts of the internal ear.

(2) The three *semi-circular canals* which are situated above and behind the vestibule, and open in their turn into the *utricle*, a part of the vestibular sac.

(3) The *cochlea*, the most important part of the essential apparatus of hearing. It is of very complicated structure and externally consists of a spiral of two and a half turns, somewhat resembling in appearance the shell of a snail. It measures about 5 mm. (¼-in.) from base to apex; its breadth, across its base, is somewhat greater.

NOTE.—Though the membranous labyrinth has the same general form as the cochlea, owing to the bony cavities by which it is completely enclosed, it is nevertheless considerably smaller, for a quantity of fluid known as *perilymph* is contained in these cavities, and separates the osseous from the membranous labyrinth. Indeed "all the sonorous vibrations which impress the auditory nerves in these parts of the internal ear are conducted through fluid to a membrane suspended in and containing fluid," for the membranous labyrinth also contains a fluid, termed *endolymph*. Both fluids are somewhat viscid, and neither are pure lymph, as they contain a small amount of mucin.

It is impossible to construct a model capable of showing with accuracy the detailed structure of the internal ear, the complications of which present great difficulties to any but those who are able to dissect specimens or to use the microcope with skill and intelligence. The functions of the semi-circular canals as the seat of the equilibrium sense, each designed to detect movements in its own plane, and the general path of the sound waves from the air through the different media (membranes, ossicles, perilymph, endolymph, sensory cells and auditory nerve) to the brain, can only be discussed, but not demonstrated.

The functions of the various parts of the ear should, however, be summarized with the aid of the model. For example, the external ear serves chiefly to collect the waves of sound; while the external meatus, closed at one end by the tympanic membrane, assists to intensify the force with which the membrane vibrates. The middle ear is so constructed as to transmit the force of the sound waves with as little loss as possible to the auditory nerve; for less energy is lost when vibrations pass through an intervening membrane, than when they are transmitted directly from air to a solid or a liquid.

The mode of attachment to the auditory ossicles provides for the required amplitude of movement, while excessive oscillation of the tympanum is guarded against by a delicate adjustment of bones, muscles and membranes. The mode of action of the internal ear is not yet fully explained. Waves of sound are apparently analysed by the cochlea, in which the vibratile hair-cells play the most important part, all the other complicated mechanism being accessory to the fulfilment by them of their delicate function.

IV.—**Dissection of a Rabbit's Ear** (adapted from Prof. Leonard Hill).

MATERIALS: *Freshly-killed rabbit; tape; drawing pins.*

APPARATUS: *Dissecting instruments and board.*

(*A*) Fasten a young, freshly-killed rabbit to the dissecting board. Skin the head; then fix it firmly by means of bands of tape, held in place by large drawing-pins.

(*B*) Remove the top and one side of the skull with strong scissors. Then scoop out the brain in order to expose the temporal bone at the base of the skull.

(*C*) Find the *external auditory meatus*; pass in a wire probe as a guide to the position of the middle ear, and cautiously cut away the temporal bone with strong sharp-pointed scissors, just over the part where the end of the probe is concealed. If great care be exercised, the middle ear with its chain of ossicles and the tympanic membrane will be exposed uninjured.

(*D*) The cochlea can be found if more of the bone which covers the middle ear be picked away with the scissors and forceps. It is a small piece of hard bone, coiled like a tiny snail's shell, and should be removed for careful examination.

V.—Tests for Hearing.

MATERIALS: *Watch; series of tuning forks of different pitches.*

(*A*) *By a watch.*

(1) Measure the distance that a ticking watch must be moved away (*a*) from the right ear, (*b*) from the left ear, before it ceases to be audible.

(2) (*a*) Hold a ticking watch between the teeth with both ears uncovered. (*b*) Repeat, closing both ears. (*c*) Repeat, uncovering one ear.

Note how the sensation of sound is affected in each instance.

(*B*) *By the voice.*

(1) Stand at a distance of 50 cms. (20-in.) from the object of the test; utter a series of figures, letters or words in a *faint* whisper. These should be audible at this distance by a normal ear turned towards the speaker. Test both ears of one or two companions in this manner.

(2) Repeat the test at a distance of 15 metres (49 ft.); using a "stage whisper" and speaking on an empty chest, *i.e.*, after an expiration. The voice should be audible in both experiments, if these tests be made in a quiet room and if the hearing be normal in both ears.

(*C*) *Compare the power of hearing* (1) through the air, (2) through the bones of the head.

(1) Strike in succession a series of tuning-forks of various pitches, and notice whether the low or the high tones are the more easily distinguished; compare your results with those of other pupils.

(2) (*a*) Repeat (1), but rest each fork in turn, while it is vibrating, upon the middle line of the head.

How does this affect your perception of the low or high tones.

(*b*) Again repeat the experiment; but rest the tuning fork on the bridge of the nose. In this case the ears should *hear* the vibrations so long as the fingers which hold the handle, *feel* them.

NOTE.—In the opinion of some authorities the watch does not constitute a test of much value, as the sound is high and impure; it may be heard distinctly by ears deaf to most ordinary tones and indistinctly by ears normal in other respects. The tests in (*C*) are sometimes employed to determine the amount and location of deafness.

In cases of imperfect hearing caused by defects of the conducting apparatus, the low tones of a tuning fork are usually less well heard than the higher. The duration of sounds, however, will be longer with those suffering from such organic ear trouble when the tuning fork is in contact with the bones of the head than is the case with those whose deafness is the result of nerve affection. When the fork rests on the bridge of the nose the vibrations will be unduly prolonged in defects of the conducting apparatus. If the nerve apparatus be at fault, the upper scale is lost first; hearing is diminished when the tuning fork rests on the head, and the duration of the vibration in (2) (*b*), is less than the normal.

(*D*) (1) Strike the tuning-fork and hold the handle between the teeth until the sound has apparently ceased.

(2) Quickly seize the fork with the hand and hold it opposite to one ear. It will be found that the fork is still emitting distinctly audible sounds.

NOTE.—This fact is attributed to the greater mobility possessed by molecules of air than by the particles of bone. Not only do the molecules of air which fill the auditory meatus move more freely, but they respond to a feebler stimulus than do bone particles.

VI.—Illustrations on "Sounds."

MATERIALS: *String; lead bullet or weight; drawing pins; tuning-fork; fragment of copper foil; small bell; water.*

APPARATUS: *Bell-jar; finger bowl; wine glasses or tumblers of different sizes; flask; 2 glass rods; indiarubber cork with 2 holes; wooden ruler; air pump; bat's-wing and ordinary Bunsen burner.*

(*A*) *To illustrate the vibration of sound waves.*

(1) Hold a bell-jar horizontally in one hand; strike it sharply with a wooden ruler, and at once put a small piece of metal (copper foil, tin foil, or well-worn small coin) inside the jar, which must continue to be held with its long axis in the horizontal position. The piece of metal will be rapidly raised from the surface of the jar by the vibrations of the glass.

Touch the rim of the bell-jar with the disengaged hand; the sound will cease and with it the movement of the metal.

(2) Take a piece of string 1 metre (39-in.) long, and securely attach to it a lead bullet or weight. Fasten the string with a drawing-pin to the edge of a table. Set it in motion, and count the vibrations in one minute.

Halve the length of the string and repeat the experiment. Halve it again and repeat. Compare the proportions borne by the number of vibrations to the length of the string.

(3) Half fill a glass finger-bowl, or large tumbler of thin glass, with water. Dip the finger in water and rub it round the rim. Notice the tremor communicated to the water by the vibrations set up in the glass by friction.

(4) Half fill a series of wine-glasses or tumblers of different sizes and shapes with water. Repeat (3). Does the result illustrate the theory that the length and rapidity of the vibrations, or sound waves, affects the pitch of the notes which result?

(5) Tie one end of a piece of string firmly to a fixed object and hold the other end tense. Twang the stretched string with considerable force. Is any connection to be traced between the rapidity of the movements which result and the character of the sounds produced?

(6) (*a*) Prepare a piece of smoked glass by blackening it over a bat's-wing gas-burner.

(*b*) Fix (by means of a small piece of wax or a touch of fish-glue) a thin strip of copper foil which tapers to a point on one prong of a tuning-fork, so that the point is in a plane at right angles to the plane of the two prongs. Strike the fork to set it vibrating; hold it in one hand, and slowly draw it along the glass with the plane of the two prongs parallel to the glass, so that the sharp point of the copper foil just touches the blackened surface.

(*c*) Repeat, but move the fork rapidly. Compare the tracings of the vibrations with those in (*b*).

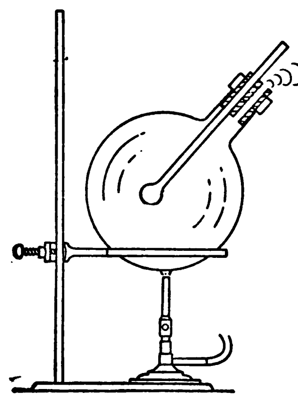

FIG. 59.

(*B*) *Effects of atmosphere on sound.*

(1) Fit up a flask as (*Fig.* 59) with an indiarubber cork pierced with two holes. Insert a piece of glass rod through one hole, and attach a small bell to the end of the rod in the flask. Ring the bell, by shaking the flask, and note the sound produced.

(2) Pour a little water into the flask, and boil briskly for a minute or two so as to drive out the air. Remove from the flame and instantly insert a piece of solid glass rod into the second hole in the cork to act as a stopper.

Allow the flask to cool, and again ring the bell. Notice the influence of a highly rarefied atmosphere upon the transmission of sound.

NOTE.—In the absence of air no sound would be conveyed, as can easily be demonstrated if all the air be exhausted from the flask by means of an air pump, and the experiment be then repeated.

Sound has been defined as "the peculiar sensation excited in the organ of hearing by the vibratory motion of bodies, when this motion is transmitted to the ear through an elastic medium." It is always the result of rapid oscillations imparted to the molecules of elastic bodies, when the state of equilibrium of these bodies has been disturbed by either friction or a shock. Such bodies tend to retain their first position of equilibrium, but only reach it after performing, on each side of that position, very rapid vibratory movements, the amplitude of which quickly decreases.

The vibrations of some sounding bodies are very readily observed, as is evident from the series of experiments just performed. The number of vibrations made by a given body when it is struck so as to produce a sound depends upon its shape, its size, its density, and its degree of elasticity. For instance, a steel tuning-fork three inches long may make 500 vibrations per second, another similar one but twice the length would make but half the number, whereas if either were made of a substance like ether, though the relative proportions would be retained, the number of vibrations made would be almost inconceivably great, amounting to millions per second. The vibrating body, whether gaseous, solid or liquid, acts as a source of waves in the medium around it.

The prongs of a tuning-fork, for instance, when struck, move outwards, push against the surrounding air and compress it slightly. The property of elasticity possessed by air ("*Air*," *page* 49) tends to a recovery of size after compression; therefore as its pressure is, as a result of compression, slightly higher than the undisturbed air around, it will recover its normal volume by compressing in turn the next layer of air. The oscillatory motion of the air consists therefore of alternate *condensation* and *rarefaction*, each part of the air experiencing in turn changes similar to those of the air subjected to the first shock from the vibrating body; this constitutes what is known as a sound wave. The buzzing and humming noises produced by certain insects are

not vocal, but result from the rapid flapping of their wings against the air or against their own bodies.

The velocity with which a wave is propagated in air or other media depends on the density and elasticity of the medium. The wave-length is calculated from the velocity; "*e.g.*, the middle C of the piano, with a frequency of 264 vibrations per second has wave-length 33,060 ÷ 264 = 125 cms., while higher notes have shorter and lower notes longer wave-lengths."

The experiment (*A*) (6) is introduced to give a general comprehension of the graphic method employed to determine the exact number of vibrations corresponding to a given note, which, briefly, consists in fixing a fine point to the body emitting the note and causing it to trace the vibrations on a properly prepared surface. When the vibrating fork is applied to the smoked glass at rest, a short line only is described on the blackened surface, but if the glass be moved the point produces an undulating line, which should contain as many undulations as the point has made vibrations. The number is counted and compared with a tracing giving a known number of vibrations in a given time.

XIII.—SPECIAL SENSE ORGANS (*contd.*).

(C) THE LARYNX.

External Observations. Dissection of the larynx of a sheep or calf.

I.—Observations on the Throat and Larynx.

MATERIALS: *Hand-mirror; wooden spatula.*

(*A*) The general construction of the throat can be studied individually by means of a hand-mirror; but a better method is to ask a companion to sit facing a good light, with his mouth wide open. If the tongue curve upwards, hold it down very gently with a spatula, a paper knife, the handle of a tea-spoon, or a piece of smooth flat wood. Avoid forcible pressure, as a feeling of nausea, or even retching, would probably result. Observe—

(1) The large, flexible, muscular, sensitive *tongue*, which nearly fills the small cavity of the mouth when this is closed.

NOTE.—In addition to the part it plays in the production of sounds the tongue serves several useful purposes in connection with the mastication and deglutition of food. It assists in mixing the saliva intimately with the food-masses while in the mouth; it rolls the masticated morsels into bolus form for swallowing, and forces them back by muscular pressure against the palate to the entrance of the pharynx. Its flexible and sensitive tip also works round and into the crevices and cavities of the teeth, expelling tiny fragments of food, which if retained predispose to caries in the teeth, in consequence of the nutritive material they furnish for micro-organisms which swarm in the warm, moist, sheltered cavity of the mouth.

(2) The *hard palate*, which forms a rigid roof over the anterior part of the cavity.

(3) The soft palate or *velum*, a continuation posteriorly of the hard palate. It is really a moveable fold suspended from the hard palate, forming an incomplete division between the mouth and the back of the throat, which is called the *pharynx*. The soft palate can be easily distinguished by the small conical, fleshy *uvula* into which it is prolonged in the middle line at the back. The posterior sides of the soft palate form double muscular pillars, which guard the opening to the back of the throat or pharynx; they are called the *pillars of the fauces*; between these the two mucous glands known as tonsils are situated, one on each side.

If the soft palate be raised, as in swallowing, communication is blocked between the nose and the mouth, for it forms a horizontal partition across the pharynx. If, on the contrary, the soft palate be lowered, the pillars of the fauces being thus brought closer together, and the base of the tongue raised, a vertical partition is formed, which closes the mouth cavity at the back, dividing it from the pharynx.

(4) Observe the position of the vocal organs when your companion takes a deep breath and says "Ah," prolonging

the sound for as long a time as possible. The soft palate is raised, and the upper part of the pharynx which, as has been said, lies behind the cavity of the mouth, becomes visible. The pharynx is that part of the alimentary canal which lies behind the nose, mouth and larynx. It may be described as a funnel-shaped bag, of which the muscular walls are attached both to the base of the skull and to the sides and floor of the mouth. The lower and narrower end passes into the gullet or *œsophagus*, the upper part terminates in a kind of vaulted roof formed of a part of the occipital bone of the skull, in which are situated the posterior openings of the nasal cavities.

(5) Observe the teeth, and their arrangement in the two jaws. If the "wisdom teeth" have been cut the jaw should contain thirty-two teeth in all. (*Fig.* 16, *page* 81.)

NOTE.—The "wisdom teeth" are *permanent*; the *temporary* teeth which precede the permanent ones only number twenty, and are shed between the ages of 6 and 12 years, when they give place to their permanent successors. In a healthy adult mouth the eight teeth on the opposite sides of both the upper and lower jaws exactly resemble each other; but the eight teeth on one side of the upper jaw differ a little in the details of their patterns from those on the same side of the lower jaw, in order that the convexities in the crowns of the teeth in the upper jaw may fit into the concavities of the crowns of the teeth in the lower jaw during mastication, and *vice versa*, thus forming an excellent grinding machine.

(*B*) (1) Loosen the collar and feel the projection in the front part of the throat commonly known as "Adam's apple"; this is one angle of the *thyroid cartilage* which forms the anterior portion of the larynx or organ of voice. It is situated between the trachea and the base of the tongue at the upper and fore-part of the neck and is a broad V-shaped cartilaginous plate with the point of the V to the front. It shelters and protects the delicate apparatus for the production of sound, which lies immediately behind it. (*Fig.* 60, *page* 267.)

Run the finger down the projecting angle, and feel the ridge formed by the bending upon itself of this plate of gristle.

(2) Find a slight depression just above the thyroid cartilage, press the finger into it quite lightly, and swallow. Observe that the Adam's apple is drawn upward and closer to the bone known as the *hyoid*, which lies at the base of the tongue.

(3) Find the *cricoid cartilage* just below the thyroid cartilage. Place the tip of the finger in the space between the two, then sound a low note and follow it instantly with another at least an octave higher.

Repeat the experiment until you have distinguished clearly—

(*a*) That the whole larynx is drawn upwards, and

(*b*) That the thryoid moves forwards and downwards, thus diminishing the space wherein the finger rests.

(4) Find the *hyoid bone*, which supports the tongue and gives attachment to its numerous muscles. Press the forefinger into the receding angle below the chin, and carry it along the length of the bone which is felt, right to its extremity, just below the angle of the jaw. Press firmly on this posterior end of the bone. This will push the whole bone over to the opposite side of the neck, when the corresponding prominence on that side will be felt distinctly, immediately beneath the skin.

Note.—Although only three of the seven distinct openings into the pharynx have been mentioned, all the openings should be enumerated and identified on a good diagram, namely the openings into the mouth, larynx and œsophagus; the openings of the two eustachian tubes above the soft palate; and those of the two posterior nares.

In calling attention to the mucous membrane with which the mouth and throat are lined, reference may be made to discomfort associated with the swelling which accompanies a severe cold or other unhealthy condition of the throat. Visual observation will show how readily any enlargement of the uvula or tonsils will lead to pain and difficulty in swallowing, or, when very severe, even in breathing. It is possible to see the top of the epiglottis if the tongue be well depressed, but the attempt is not to be recommended for inexperienced observers. In thin people, especially in lads, the general form of the whole larynx may be easily felt.

It is most important to caution pupils against introducing the same instrument used for depressing the tongue into more than one mouth, unless well boiled intermediately before being used again, in order to sterilize it first. The constant presence of micro-organisms in the mouth and throat, occasionally of a pathogenic character, forbids any carelessness in this respect. The instruments should be well boiled as a routine practice at the close of each class at which they have been employed.

II.—Dissection of the Larynx of a Sheep or Calf.

MATERIALS: *Larynx of a sheep or calf; hand-mirror; 2 strips of sheet rubber; thread.*

APPARATUS: *Dissecting board and instruments; wooden or metal tube; pair of bellows.*

NOTE.—The larynx of either a sheep or calf can be used equally well for this dissection. In either case ask the butcher to supply the tongue, with the larynx, windpipe and gullet attached.

(*A*) *Make a careful external study of the specimen.*

Distinguish:—

(1) The windpipe or *trachea* with its rings of cartilage.

(2) The thick muscular tube, the gullet or *œsophagus*, closely adherent to the trachea.

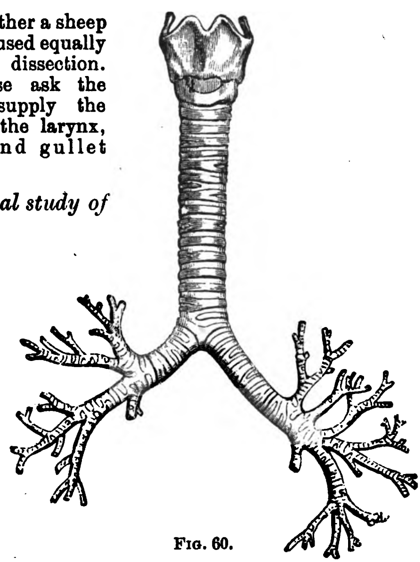

FIG. 60.

(3) The voice box or *larynx* at the upper part of the trachea, and the thin muscular bands with which the larynx is covered.

Endeavour to trace some of these up to

(4) the small bony arch, or *hyoid* bone, embedded in the muscles below the root of the tongue. This forms the

point of attachment for muscles which pass upward to the tongue and downward, not only to the *thyroid* cartilage, but to the *sternum*. This bony arch is itself kept in position by muscles and ligaments, which are attached to the tip of the *styloid processes* of the temporal bones of the skull.

(*B*) *Continue the dissection:*—

(1) Expose the thyroid cartilage by cutting the tissues, muscular and otherwise, carefully away from the front and sides. Observe the bands of muscles attached to the cartilages on each side, and follow their course round behind the gullet.

(2) Raise the *epiglottis* and look down into the larynx; two ridges or folds of mucous membrane will be seen; just projecting from the sides of the *glottis*; these are the *vocal chords*, the vibration of which, by currents of air passing through them, produce the voice.

NOTE.—When the larynx is at rest, as in quiet breathing, the vocal chords are very difficult to detect. They are attached closely to each other in front, but diverge widely at the back when at rest. When changes occur in the breathing, or when vocal sounds are produced, they become more or less parallel and tense. The note emitted will be high or low, according as the cords are tightened or relaxed. The tension of the vocal chords is voluntarily controlled by means of a complicated arrangement of muscles; so that high or low, loud or soft sounds can be emitted at will. The quality of a voice (as treble, tenor, &c., in a human being) depends largely upon the particular formation of the larynx, and the length and elasticity of the vocal chords.

(3) Remove the gullet and the muscular band behind the thyroid cartilage; then thoroughly examine the glottis, and the epiglottis.

(*a*) The *glottis* is the slit or chink situated immediately behind the tongue, at the lower and anterior part of the pharynx. It forms the upper aperture of the windpipe, and is the lowest part of the cavity of the larynx; but both width and shape vary during respiration and voice produc-

tion. The edges of this slit, which runs from front to back of the larynx, are called the *vocal chords* or *vocal ligaments.*

(*b*) Look for the *epiglottis*, a thin, cartilaginous, leaf-shaped body, placed behind the tongue, but in front of the superior opening of the larynx. Observe the shape of the free extremity and demonstrate how it closes the larynx. Move it up and down, forwards and backwards, to realise its range of movement, which is involuntary in character. Notice also the smooth surface it offers for the passage of a food bolus down into the *œsophagus.*

NOTE.—When air is expired through the larynx, the edges of the vocal chords vibrate more or less rapidly in proportion to the degree of tension induced, and vocal sounds are the result. According as they are tightened or relaxed by the very complicated action of the muscles, ligaments and cartilages of the larynx, they become more or less parallel, and notes of different pitch are the result.

(4) Examine the *cricoid cartilage*, anteriorly narrow, posteriorly broad; note that it forms a firm protection for the back of the larynx. Move it to and fro to prove that it is entirely separate from the thyroid cartilage.

(5) Notice the *sheet of muscle* which unites the *thyroid* and *cricoid cartilages.* Move the cricoid to and from the thyroid, in order to see how the tension of this muscle is affected as the distance between the cartilages is increased or diminished. It is by their movements that the tension of the vocal chords is chiefly determined. Remove the muscle from one side of the larynx in order to observe more minutely the mode of articulation between the thyroid and cricoid cartilages. Observe also that all the ligaments and muscles of the larynx allow considerable range of movement to its various parts, an arrangement absolutely necessary for the production of varied sounds.

NOTE.—Mention must be made of the *arytenoid cartilages*, which by their relative distances from each other, play an important part in the position (parallelism) of the vocal chords, or more accurately of the vocal ligaments. Skilful dissection

is required to find them, as they are concealed by the muscles and vocal chords. They are two curved, yellowish cartilages, which project upward and backward from the top of the larynx. They are freely moveable, and are perched on the upper edge of the posterior portion of the cricoid cartilage.

If the directions given above be carefully followed pupils will gain an accurate, though elementary, knowledge of the position and structure of the larynx. If of several specimens provided for a class one be cut open lengthwise, in the middle line in front, and another be similarly cut open from the back, some assistance will be afforded in the clear comprehension of the relative positions and characteristic structure of the various parts.

In quiet breathing the vocal chords lie so closely against the sides of the larynx that not only are they difficult to distinguish, but nearly the whole aperture is left free for the passage of air. When it is desired to produce a vocal sound the laryngeal mechanism of cartilages, ligaments and muscles enables the vocal chords to project more or less into the channel; thus they interfere with the passage of air, which causes them to vibrate as it is driven past them. The quality, quantity and pitch of the sound depend upon the force with which this takes place, the size and condition of the chords, the rapidity of the vibrations, and the form of the larynx; and these in their turn, are determined by the size of the larynx, upon which the length of the chords depends. When the mucous membrane of the larynx is swollen or otherwise unhealthy the normal tones of the voice are affected to a greater or less degree; hoarseness and loss of voice being the result of inflamation or roughness of the edges of the vocal chords.

(C) *To illustrate the passage of air through the glottis.*

Take a wooden or metal tube and two strips of sheet rubber, of which the size must be adapted to the diameter of the tube selected. Stretch them over the open end of the tube, and tie them firmly in position with thread, leaving a chink between them. Their edges represent the vocal chords, and the chink represents the glottis.

Connect a pair of bellows by means of a piece of india-rubber tubing with the free end of the tube, and force air between the rubber strips; if these are not too far apart

nor too thick sound will be produced. Tighten or loosen the strips; and notice how the sound varies in tone according to the tension of the bands.

(*D*) *With the aid of a hand-glass observe how the modulation of voice into speech is brought about.* (*Adapted from Huxley's "Lessons in Elementary Physiology."*)

(1) By changing the form of the cavity of the nose and mouth.

(2) By the action of the muscles which move the walls of these parts.

(*a*) Take a deep inspiration, and while slowly expiring with the mouth open, pronounce the following pure vowel sounds:—

"E" (as in *he*). "A" (as in *hay*). "A" (as in *ah*).
"O" (as in *or*). "O" (as in *oh*). "OO" (as in *cool*).

Notice that the form of the mouth and the extent to which the lips are thrust out or drawn in, in order to lengthen or shorten the distance of the orifice from the larynx, are changed for each vowel. The aperture of the mouth will be narrowest with the lips most drawn back, in "E," widest in "A," and roundest, with the lips most protruded, in "OO."

(*b*) Repeat (*a*) but pronounce the following consonants:— "H" (aspirated), "S," "Z," "Sh," "J" (as in *jugular*), "Th," "L," "R," "F," and "V," each in turn.

Notice that as the air is forced through the mouth the shape of the cavity is peculiarly modified by the tongue and lips; but in neither (*a*) nor (*b*) is any stoppage involved of the current of air as it traverses either of the modulating passages (the nose and mouth).

(*c*) Pronounce "M," and "N." A free passage is left to the air through the nose; but for "M," the

mouth is shut by the lips, for "N," by the application of the tongue to the palate; if the nostrils be closed by the finger and thumb, neither of these letters can be properly sounded.

(*d*) Pronounce "B," "P," "T," "D," "K," "G" (hard, as in *go*).

Notice that to produce these sounds the passage of air through both nose and mouth is blocked, the expiratory vocal current being forced through the obstacle furnished by the mouth, the character of which obstacle gives each consonant its peculiarity. Observe that "B" and "P" force the mouth open in an *explosive* manner; in "T" and "D" the mouth passage is suddenly *barred* by the application of the point of the tongue to the teeth or to the front part of the palate; while in "K" and "G" hard the middle and back of the tongue are similarly forced against the back part of the palate. All the above letters can be properly sounded when the nostrils are closed by the finger and thumb.

NOTE.—The shape, size and position of the air passage attached to the larynx so materially affect the quality of sound produced that there are no two voices exactly alike, and each voice has its characteristic intonation. A great number of complex movements are needed to produce speech, and the centre for their control in the brain develops but slowly. The *quality* and *timbre* of speech are so much influenced by imitation that children should be surrounded so far as possible with adults whose speech is refined and distinct.

Enlarged tonsils or adenoid vegetations affect the resonance of the voice and by blocking the free passage of the sound waves to the nasal cavities compel an adjustment of the muscles concerned in articulation which strains the larynx, and frequently results in weak or husky voices. Defective respiration brings about a similar class of results. For instance, if the bad habit of speaking on an empty chest be acquired, the delicate laryngeal muscles are subjected to severe and unnatural strain, which predisposes to many forms of temporary voicelessness or to sore throats. Similarly,

constant efforts to make the voice heard above loud and continuous noise strain the sensitive vocal mechanism and lead to throat trouble. Distinctness of articulation actually carries further under such circumstances than raising the voice.

Three principal groups of muscles are concerned in voice production, (1) the respiratory muscles which control the flow of air; (2) the muscles which control the movements of the vocal chords; (3) the muscles of articulation which are concerned in moulding sounds in the mouth. All these must act together harmoniously and in their right order.

Stuttering and *stammering* are caused by want of harmony in the respective contraction of these muscle groups, in respect either of their order, their duration or the degree of their contraction. To correct the habit of stammering in children it is necessary (1) to train them by suitable exercises in right methods of breathing, so that the respiratory muscles act freely and regularly, and that the chest is always full of air when the effort to speak is made; (2) to this training must succed a similar education of the muscles of phonation, so that they respond normally to the right degree of stimulus; (3) finally, when both (1) and (2) have become automatic, the exercises must be combined with articulation, great care being taken to free children predisposed to this form of nervous and muscular spasms, from embarrassment and self-consciousness, and to inspire them with reasonable self-confidence.

PART III.

XIV.—SOME PROPERTIES OF PROXIMATE FOOD PRINCIPLES.

Introductory Note. The properties of Proteids. The properties of Carbohydrates. The properties of Fat.

NOTE.—Food is necessary to the body for the following reasons:—

(1) From it the tissues and fluids are formed of which the body is composed, while through its means the wastes and losses are repaired which these tissues sustain in the maintenance of the vital processes and in the performance of daily activities.

(2) A small proportion of the food eaten or drunk is stored, in forms much changed by the process of digestion, for future use by the body, but the greater proportion is immediately consumed as fuel, the potential energy contained in the different food-stuffs being transformed as occasion demands into heat or other forms of energy such as muscular activity, according to the requirements of the moment. Thus, while food builds and repairs the body it also serves as the source of heat and power.

(3) Again, certain kinds of food preserve the tissues of the body, or even the substance of other foods, from consumption in the course of their dissolution by the digestive juices.

The fact is, therefore, to be anticipated that food-stuffs should and would contain the same elements, combined into the same proximate principles, as those of which the body itself is composed, *e.g.*, nitrogen, carbon, oxygen, hydrogen, etc. (*Fig*. 41, *p*. 179). Chemical analysis confirms this anticipation, while experience proves that each and all of these substances must be represented in the daily diet if health is to be maintained.

Proteids, *water* and *salts* are the principal tissue formers in food stuffs, *carbohydrates* and *fats* are the chief fuel ingredients.

It is believed that proteids, carbohydrates and fats can, to a greater or less degree, and more or less temporarily, replace one another in the nutrition of the body, though neither fats or carbohydrates can serve as entire substitutes for proteids in the daily diet. Nevertheless, when the supply of proteids is limited, the former, by being themselves first consumed, preserve these most important of all food principles from undue or complete consumption. The animal organism can convert fat into carbohydrates or carbohydrates into fats to meet its immediate necessities, but no such transformation of non-nitrogenous food into nitrogenous proteids can be effected, though probably the body can produce both carbohydrates and fats from proteid material.

Thus proteids, fats and carbohydrates all furnish *energy* and *heat*, but the first alone can replace the constant loss of living protoplasm by the tissues. It is naturally important that this waste of tissue shall be made good by fresh material in suitable form as food, and the accurate adaptation of this supply to the daily demand is described as the maintenance of nitrogenous equilibrium.

The energy evolved as the food is consumed in the body can be measured by means of an apparatus called the calorimeter (*page* 78). The unit employed for the purpose is known as the *small calorie*; it represents the amount of heat required to raise the temperature of 1 gram of water 1° C. The *large Calorie* (always spelt with a capital C), is also used as the heat-unit by some authorities; it equals 1,000 small calories and represents the heat required to raise the temperature of one kilogram of water 1° C, or of one pound of water 4° F.

When the nutrients are compared in respect of their fuel values, *i.e.*, as to their capacities for yielding heat and mechanical power, it is shown that on an average 1 gram of proteid equals 4·1 calories, 1 gram of carbohydrates equals 4·1 calories, and 1 gram of fat equals 9·3 calories or more than double the amount of the first two. That is, 28·35 grams (1 oz.) of lean meat or of egg albumin is just about equal as a source of heat to 28·35 grams (1 oz.) of starch or sugar, or to about 14·17 grams (½ oz.) of butter or suet.

The unit of *mechanical energy* (·1381 Kgm., or 1 foot-pound) may be substituted for the unit of heat when it is desired to calculate the *work* equivalent of any form of food-stuff or of

any specified dietary. This represents the force equivalent to the strength expended in raising a weight of ·1381 kilograms one metre from the ground, or of one pound one foot from the ground. The metric equivalent of the foot-ton (310 kilograms) is however more convenient for purposes of general use, and corresponds to the large Calorie as an index of energy in the form of heat. The following tables are useful for purposes of calculation, reference or comparison, dietetic and economic.

1 gram of proteid ...	= c 4·1;	Kgms 8·75;	Foot-pounds 6·3
1 gram of carbohydrate	= c 4·1;	Kgms. 8·75;	Foot-pounds 6·3
1 gram of fat	= c 9·3;	Kgms. 19·47;	Foot-pounds 14·2

THE NUMBER OF CALORIES OBTAINABLE FOR A SHILLING, WITHOUT DEDUCTIONS (*after* HUTCHISON): –

Refined Cotton-Seed Oil	16,740
Fine Flour at 1/2 the dozen lbs.	15,696
Hutchinson Bread at 1½*d*. per lb.	10,764
Oatmeal	10,894
Beet Sugar	10,186
Peas	8,921
Lard, Dripping, Margarine at 4*d*. per lb.	8,652
Herrings, 2 for 1*d*.	4,811
Potatoes	3,796
Milk	3,000
Butter	2,984
Cheese	2,638
Apples	1,529

The work or fuel value of the food consumed should vary within considerable limits according to the age, sex, class of occupation, state of health and environment of the individual (*Fig*. 61).

Until quite recent years most authorities agreed that a man in the prime of life, performing a good day's work, required an amount of food daily equivalent to a fuel value of about 3,000 calories, represented by 118 grams (4½ ozs.) of proteid, 56 grams (2½ ozs.) of fat and 500 grams (nearly 1 lb.) of carbohydrates; the proportion of 1 part of nitrogen to 15 of carbon being always as nearly as possible maintained.

The following table of standard dietaries illustrates what, for some years, has been accepted by the authorities quoted, as the ratio of food principles necessary to a well-proportioned diet.

	Proteid Grams.	Fat Grams.	Carbo-hy-drates Grams.	Total Grams.	Calor-ies.
VOIT.					
Woman at moderate work (German) ...	92	44	400	536	2,425
Man at moderate work (German)	118	56	500	674	3,055
Man at hard work (German)	145	100	450	695	3,370
PLAYFAIR.					
Man with moderate exercise (English) ...	119	51	531	701	3,140
Active labourer (English)	156	71	568	795	3,630
Hard-worked labourer (English)	185	71	568	824	3,750
ATWATER.					
Woman with light exercise (American) ...	80	80	300	460	2,300
Man with light exercise (American) ...	100	100	360	560	3,815
Man at moderate work (American) ...	125	125	450	700	3,520
Man at hard work (American)	150	150	500	800	4,060

The following Examples of Daily Diet have been constructed by Dr. Brown Ritchie of Manchester to illustrate these theoretical calculations.

No. I.

Materials.	Price.	Proteid.	Fat.	Carbo-hydrate.
Bread. 1 lb.	1*d.*	29·75	4	232·25
Potatoes	¾*d.*	5·4	—	85·95
Milk, 1 quart	3½*d.*	35·4	35·4	50·25
Rice, 25 grammes at 3*d.* per lb.	⅙*d.*	1·8	0·25	19·2
2 herrings = ½ lb., cooked	1*d.*	50·12	19·6	—
Bacon, 2 ozs.	¾*d.*	4·56	36·68	—
Margarine, 1½ ozs.	7/16*d.*	—	36	—
Sugar, 2 ozs.	¼*d.*	—	—	56·25
Tea, ¼ oz....	¼*d.*	—	—	—
Price ...	8 5/48*d.*	127·03	131·93	443·9

Breakfast : Milk 1 pint, 1 herring, ¼ lb. bread, ½ oz. margarine.

Dinner : Bacon 2 ozs., fried potatoes ½ lb., rice pudding 1/18 lb., milk 1 pint.

Tea : Tea ⅛ oz., sugar 1 oz., margarine ½ oz., bread ½ lb., 1 herring.

Supper : Potatoes fried in bacon fat ½ lb., margarine ½ oz., bread ¼ lb.

No. II.

Materials.	Price.	Proteid.	Fat.	Carbo-hydrate.
Mutton, ½ lb.	3*d.*	32·63	43·87	—
Milk, 1 quart	3½*d.*	35·4	35·4	50·25
Suet Pudding, 2 ozs. (1 oz. suet, 1 lb. flour)	0·35*d.*	5·80	10·98	—
Porridge (2 ozs. oatmeal)	⅜*d.*	7·99	4·11	37·07
Rice, 2 ozs., husk removed	⅜*d.*	4·05	1·13	43·2
Bread, 1 lb.	1*d.*	29·75	4·0	236·25
Sugar, 2 ozs.	¼*d.*	—	—	56·25
Tea, ¼ oz....	¼*d.*	—	—	—
Cheese, 1½ ozs.	$\frac{9}{16}$*d.*	13·424	12·55	—
Turnip, ¼ lb.	¼*d.*	1·01	—	5·62
Margarine, 1½ ozs.	⅝*d.*	—	36·0	—
Cost of Diet ...	10·6*d.*	130·05	148·04	428·64

Breakfast: Porridge (2 ozs. oatmeal), milk 1 pint, bread ¼ lb., margarine ½ oz.
Dinner: Mutton ½ lb., turnip ¼ lb., suet pudding 2 ozs., sugar 1 oz.
Tea: Tea ¼ oz., bread ¼ lb., margarine ½ oz., sugar 1 oz.
Supper: Bread ½ lb., cheese 1½ ozs., margarine ½ oz., rice pudding (2 ozs. rice), milk 1 pint.

Professor Chittenden of Yale University, U.S.A., has however recently demonstrated that actually *half* this amount of *proteid* appears, as the result of numerous scientifically conducted experiments, to suffice for the physiological needs of the adult body under ordinary conditions of life, while at the same time, *considerable diminution* in the proportion of *non-nitrogenous* substances seems to meet the requirements of healthy men of various ages very diversely employed in mind and body. This would, of course, represent a substantial reduction on the number of heat calories yielded by the daily diet. The subjects of Professor Chittenden's experiments were engaged in most diverse and varied occupations and enjoyed excellent health while under his observations, which extended over many months.

Dr. Folin, another American physiological chemist, has also conducted some careful experiments and analyses which indicate that about 20 grams (¾ oz.) of proteid represent the actual daily proteid wastes of an average-sized man leading a normal life, so that it is presumably a fair inference that a similar amount only is required to make good the loss.

One very practical result, if these experiments be confirmed by further tests, would be the great saving of expense

which would accrue could the daily consumption of food be so materially reduced. Dr. Halliburton, however, considers that for English people the dietary standards of Ranke and Moleschott do not seem over generous, climate being a factor of great moment in all dietary calculations. Dr. Langworthy (U.S.A.) draws attention to the fact that any race living on a small amount of proteid or on a large amount of vegetable food, such as the Hindoos or the Italians, are not "capable," neither are they really good workers until their dietary standard is re-arranged.

If it become necessary to revolutionize in the near future dietary standards which have been proved by long experience to give satisfactory results in health and strength, very careful consideration must first be accorded to the whole complex question of the factors which influence nutrition. In any case, the personal factor is strong in the amount of food consumed by each individual, so that general principles only, and no hard and fast rule, can be laid down for guidance.

In childhood a liberal and practically unrestricted supply of the nutrient principles is desirable in the diet; after twenty-five, less carbohydrates are necessary as muscular activity diminishes, while those who desire a happy, healthful and useful old age will exercise the strictest moderation in diet, combined with a gradual reduction in the quantity of each proximate principle after maturity, that is from about the age of fifty onwards (*Fig.* 61 *on next page*).

Assistance in the regulation of diet, in the methods of palatable and wholesome cooking, and in the provision of food and drink, is derived from even an elementary study of the proximate principles present in food-stuffs; this should include observations on their characteristics and behaviour when exposed to heat, etc., and some acquaintance with the care necessary to their preservation in order to meet the needs of modern life (*see Sections XVI. and XX.*) (*Fig.* 62 *on next page*.)

The extract (*page* 281) from "*Food and Dietetics*," Part I., published by the "American School of Household Economics," will assist in a practical comprehension of the limitations to be taken into account when employing tables of the chemical analysis of food-stuffs as guides for dietary calculations, while at the same time it will show what a useful purpose is also served by such tables when used with intelligence and discretion.

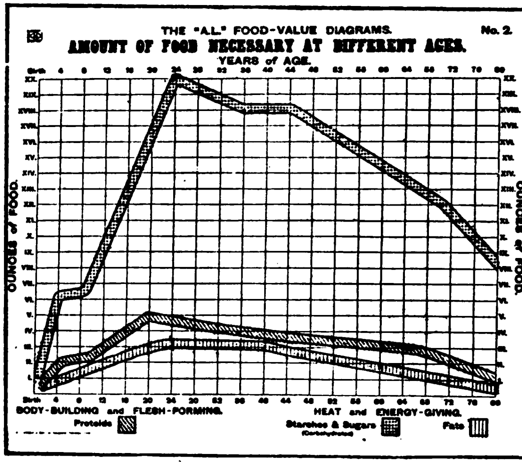
THE "A.L." FOOD-VALUE DIAGRAMS.
No. 2.
AMOUNT OF FOOD NECESSARY AT DIFFERENT AGES.
YEARS of AGE.
OUNCES of FOOD.
BODY-BUILDING and FLESH-FORMING.
Proteids
HEAT and ENERGY-GIVING.
Starches & Sugars
Fats

FIG. 61

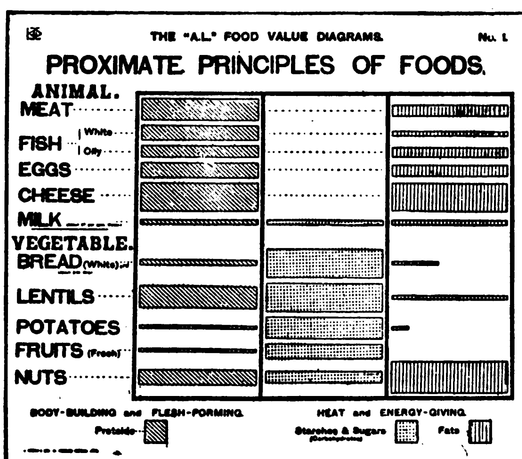
THE "A.L." FOOD VALUE DIAGRAMS.
No. 1.
PROXIMATE PRINCIPLES OF FOODS.
ANIMAL.
MEAT
FISH
White
Oily
EGGS
CHEESE
MILK
VEGETABLE.
BREAD (White)
LENTILS
POTATOES
FRUITS (Fresh)
NUTS
BODY-BUILDING and FLESH-FORMING.
Proteids
HEAT and ENERGY-GIVING.
Starches & Sugars
Fats

FIG. 62.

"We must not fail to distinguish between the amount of proteid required and the amount of food which contains this proteid. If, for example, meat be supplied containing 18 per cent. of proteid (a fair average), a little more than a pound and a half of the meat will be required to furnish the daily allowance of four and a half ounces of proteid. Bread containing 9 per cent. of proteid would be required to the amount of three pounds. Nearly two pounds and a quarter of eggs, with 13·1 per cent. of proteid, or about eighteen eggs, would be neccessary to supply four and a half ounces of pure proteid.

"A pint of milk, weighs about 1 lb., so about 4½ quarts would be required to provide 4·5 ozs. of proteid. A bushel of potatoes weighs about 60 lbs., consequently about one peck of potatoes would be required.

"It is by no means a matter of indifference whether the proteid be derived from any one of these food materials, or from a mixture of different ones. The other food ingredients present must be taken into account. For example, the three pounds of bread would furnish also more than a pound and a half of carbohydrates, a great excess of the required amount. The meat would vary in fat, but estimating the per cent. as twenty, the pound and a half would yield four and eight-tenths ounces, more than would be required for the day. The quantities used of these different foods must then be so adjusted that the nutrients will be in approximately the right proportion. The deciding upon these different quantities from the percentage composition of the food is the essential point in calculating dietaries."

The following table (*p.* 282), adapted from Dr. Hutchison's calculations, throws much light upon this question of the relative cost and composition of many articles of food in daily use.

COMPOSITION OF FOODS (AFTER HUTCHISON).

100 Grammes of	Prices.	Water.	Proteid.	Fat.	Carbo-hydrate	Salts.
Beef, medium fat ...	6*d*. per lb.	76·5	20·0	1·5	—	1·3
Mutton, lean	5*d*. ,,	75·0	18·0	5·7	—	1·3
,, medium fat	6*d*. ,,	65·2	14·5	19·5	—	0·08
,, very fat ...	6*d*. ,,	46·0	10·2	43·2	—	0·06
Pork, medium fat ...	6*d*. to 8*d*. per lb.	60·9	12·3	26·2	—	0·05
,, very fat... ...	——	44·4	9·7	45·5	—	0·01
Bacon	6*d*. per lb.	22·8	8·1	65·2	—	4·4
Liver, ox	4*d*. ,,	71·2	20·7	4·5	1·5	1·6
Heart, ox	3½*d*. ,,	62·6	16·0	20·4	—	1·0
Tripe	3*d*. ,,	74·6	16·4	8·5	—	0·5
Herring, cooked ...	2 for 1*d*. = ½ lb.	52·99	23·67	8·72	—	—
Cow's Milk, average	3½*d*. quart	87·4	3·5	3·5	5·0	0·6
Butter	1*s*. per lb.	15·0	2·0	82·0	—	—
Margarine	8*d*., 6*d*., 4*d*. per lb.	9·3	1·3	82·7	—	6·7
Cheese, American ...	6*d*. per lb.	26·9	32·9	31·0	—	4·5
,, Cheshire ...	6*d*.—9½*d*.	33·2	29·4	30·7	—	4·3
Fine Flour	1¼*d*. to 1½*d*. per lb.	13·0	9·5	0·8	75·3	0·7
Oatmeal	2*d*. per lb.	7·2	14·2	7·3	65·9	1·9
Pearl Barley	3*d*. ,,	12·7	7·4	1·2	76·7	1·2
Rice, husk removed...	3*d*. ,,	12·0	7·2	2·0	76·8	1·0
Bread, white	2*d*. = 2 lb.	40·0	6·5	—	52·5	1·0
Whole Meal	,, ,,	45·0	6·3	—	47·5	1·2
Hovis	3½*d*.=2lb. (Flour 2*d*.)	45·0	9·9	—	42·3	1·2
Macaroni	4*d*. = 1 lb.	12·0	10·89	0·65	75·70	0·50
Semolina	3*d*. = 1 lb.	10·6	11·96	0·60	75·79	0·65
Dried Peas ...	1½*d*. Split Peas; 2*d*. and 2½*d*. Marrowfat	13·0	21·0	1·8	55·4	2·6
Lentils	2*d*. per lb.	11·7	23·2	2·0	58·4	2·7
Haricot Beans ...	2*d*. ,,	11·7	23·0	2·3	55·8	3·2
Potatoes ...	1*s*. 2*d*. per score Best	76·7	1·2	0·1	19·1	0·9
Carrots	2 lb. for 1*d*.	85·7	0·5	0·3	10·1	0·9
Turnips... ...	2 lb. for 1*d*. (given as 5 lb. for 2*d*.)	90·3	0·9	0·06	5·0	0·8
Cabbage	1*d*. to 2*d*. for 1	89·6	1·8	0·4	5·8	1·3
Cauliflower	3*d*.	90·7	2·2	0·4	4·7	1·2
						Acids
Apples	2*d*. per lb. (very dear)	82·5	0·4	0·5	12·5	1·0
Currants	5*d*. per lb.	27·9	1·2	3·0	64·0	2·2
Raisins	6*d*. ,,	14·0	2·5	4·7	74·7	4·1
Best Sugar	1 lb. for 2*d*.	2·9	—	—	92·0	2·56
Treacle	,, ,,	28·4	—	—	69·7	—
Honey	1 lb. for 6*d*.	19·98	—	—	78·95	—
Lard	4*d* to 6*d*.	—	—	—	—	—
Suet	6*d*. to 8*d*.	—	—	—	—	—
Dripping	4*d*. to 6*d*.	—	—	—	—	—
Eggs	1 = 2 ozs. for 1*d*.	65·5	13·1	9·3	—	—

"The question," continues the writer just quoted, "will probably come to each one—of how much practical use for the every-day housekeeper is this study of dietaries. In the first place, it would mean the expenditure of a great deal of time if one should undertake to determine each day's rations in this way. In the next place, it is impossible to know the actual composition of the food that we eat, except in a few cases. We may be fairly sure of the composition of the egg, but when meat varies in proteid from 12 per cent. to 22 per cent. as it does according to the Atwater analyses, how are we to determine the composition of the particular cut that we are using to-day? Moreover, even if our meal were prepared so that the exact proportions of nutrients were furnished, it is quite possible that one member of the family might eat too large a proportion of the proteids and another too much of the carbohydrates.

"Another element of uncertainty lies in the difference in composition between cooked and uncooked food. Rice, for example, according to the tables, contains 79 per cent. of carbohydrate and 7·8 per cent. of proteid. But if you will weigh a cup of rice before it is cooked, and the same rice after it is cooked, you will find that it has gained perhaps four times its original weight. In other words, a quarter of a pound of cooked rice will only furnish about a fourth as much nutrient as a quarter of a pound of rice without the added water. Often we can allow for this difference in the calculation of our dietary; but sometimes we know too little about the changes which take place in cooking to do this. Finally, even if we know exactly what we eat we do not know what we assimilate. Is there, then, any use in the dietary standard?

"In two ways it is of great service. In the first place, it is a standard by which we may test our diet if we extend our experiment over a sufficiently long period. At the beginning of a month let us take account of stock, estimate the amount of food materials on hand, and then keep a careful account for a month of all food brought into the house; at the end of the month we will again estimate what we have on hand and in this way ascertain the amount of raw material used. If, on calculating the food value of the different materials, we find that for the number of persons served we have a distinct variation from the standard diet, we can legitimately conclude that there is something wrong. If, for example, we find that the amount of proteid calculated in our food-

materials is twice as much as that supposed to be required, we shall conclude that either our families must be using a much larger amount of proteid than would be conducive to the best health, or there must be much unnecessary waste, and in either case, an investigation would be needed.

"Another way in which the dietary standard is of especial service is in enabling us to judge what error in diet is responsible for some particular weakness or peculiarity in any member of the family. A girl of fourteen may be unusually thin or may appear languid and tired, and everything point to improper feeding as the cause. The first thing to do, in this case, would be to see whether the child's diet were deficient in any of the three nutrients, and if so bring the diet up to the standard. In dealing with abnormal conditions, then, or with large masses of people, or with diet over an extended length of time, the dietary standard may be applied to great advantage. It is not necessary to apply it strictly to each individual at each meal.

"The calculation of a few dietaries is very useful in giving us a definite idea of the general composition of foods, and so making it easier to estimate the amount of different nutrients which we are providing at ordinary meals, without the tediousness of reckoning each meal in detail.

"In such calculations the following factors used by the U.S. Department of Agriculture in Calculating Meals Consumed in Dietary Studies, are used to reduce the results to the standard of one man at moderate work.

"A Man at hard muscular work requires 1·2 the food of a man at moderately active muscular work.

"A Man with light muscular work, or a boy 15 to 16 years old, requires 0·9 the food of a man at moderately active muscular work.

"A Man at sedentary occupation, a Woman at moderately active work, a Boy, 13 to 14, or a Girl 15 to 16 years old requires 0·8 the food of a man at moderately active muscular work.

"A Woman at light work, a Boy 12, or a Girl 13 to 14 years old requires 0·7 the food of a man at moderately active muscular work.

"A Boy 10 to 11 and a Girl 10 to 12 years old requires 0·6 the food of a man at moderately active muscular work.

"A Child 6 to 9 years old requires 0·5 the food of a man at moderately active muscular work.

"A Child 2 to 5 years old requires 0·4 the food of a man at moderately active muscular work.

"A Child under 2 years old requires 0·3 the food of a man at moderately active muscular work."

I.—The Properties of Proteid.

MATERIALS: 2 *fresh eggs; gelatine;* 2 *ozs. fresh, raw, lean beef; nitric acid; absolute alcohol;* 10% *solution sodium chloride; vaseline; strong tea; neutral litmus paper; filter paper; water.*

APPARATUS: *Beakers; test tubes;* 3 *Petrie dishes; funnel; glass rods; slips of glass; tumbler;* 3 *small basins; bell-jar; glass measure; thermometer; sand-bath; retort stand; Bunsen burner.*

(*A*) *Egg Albumin.*

(1) Break a fresh egg into a basin, separating the albumin from the yolk.

Note that the albumin is colourless, almost tasteless and glutinous. Drop a piece of neutral litmus paper into the albumin, observe the result and determine whether it be acid or alkaline.

(2) Put 5 c.c. albumin into a test tube containing cold water. Stir the mixture gently, and observe whether the albumin mixes readily with the water.

(*B*) *Effects of Temperature upon Albumin.*

(1) Place a small quantity of fresh, raw egg albumin in a clean, dry test tube. Support a thermometer in the tube, and place both in a beaker of water on a sand-bath over a Bunsen burner. The bulb of the thermometer must be immersed in the albumin.

At what temperature does the albumin (*a*) cloud, (*b*) become opaque, (*c*) solidify? (Stir the water in the beaker during the heating process, it contributes to the more even heating of the albumin.)

After raising the temperature to 60° C. (140° F.) shake the contents of the tube into the tumbler of water, and note whether it undergoes any further change. Observe whether the heat affects the clearness of the solution, and if so, at what temperature. Note if any coagulation occurs as the heat is increased.

(2) (*a*) Run some fresh egg albumin into a porcelain basin, cut it well with scissors and place a small quantity in a wide-mouthed bottle fitted with a stopper. Add 10 volumes of distilled water, shake vigorously, and when the mixture has frothed invert the bottle over a beaker half full of water.

Allow the bottle to remain in this position until the froth and proteid particles float on the surface; then carefully remove the stopper and allow the liquid (but not the scum) to mix with the water in the beaker. If this becomes strongly opalescent (due to traces of globulin) filter through double butter muslin, then test the filtrate with litmus paper; if alkaline, neutralise it with a weak solution (2%) of acetic acid.

(*b*) Heat 20 c.c. of the filtrate to boiling point in a test tube; add, drop by drop, some of the dilute acetic acid solution until a precipitate forms.

NOTE.—The application of heat to pure egg albumin results in the formation of a white, opaque mass. This change occurs at a temperature of about 70° C. (158° F.) and is called *coagulation*, it is characteristic of most albuminoids, and is associated with the loss of their property of solubility in water.

In the case of dilute solutions of egg albumin it will be observed that no precipitate forms unless the solution is acid.

(*C*) *Effects of Acids and Alcohol upon Albumin.*

Place a small quantity of pure, fresh egg albumin in three test tubes (*a*) (*b*) (*c*). Add to:—

(*a*) 1 c.c. nitric acid.
(*b*) 2 c.c. pure alcohol.
(*c*) 5 c.c. strong tea, which has "stewed" for 20 minutes.

Set aside, and compare, after 15 minutes, the results upon the albumin.

NOTE.—Any strong mineral acid or mineral salt added to a solution of proteid will cause a coagulum to form.

Certain other bodies, such as tannin, yield a similar result. ("*Beverages*," V., (*A*) (2), *infra*.)

The addition of alcohol at first forms a precipitate; but if this be kept standing for some time under the alcohol, it changes into a coagulum. ("*Beverages*," V., (*E*) (1), *infra*.)

(*D*) *The Putrefaction of Albumin.*

Take two small basins (*a*) and (*b*). Place 10 c.c. of fresh egg albumin in (*a*) and cover with a bell-jar or beaker, kept moist on the inner surface by occasionally rinsing out with water.

Sterilise (*b*), (*page* 42), before adding 10 c.c. fresh egg albumin, cover with a slip of sterilised glass sealed round the edges with vaseline.

Set both aside under similar conditions of temperature and light.

After a few days, note any difference between (*a*) and (*b*) in respect of appearance, smell, or other characteristics.

NOTE.—Though both *putrefaction* and *fermentation* are the work of living agents (bacteria, moulds, and yeasts), the process of putrefaction differs from that of fermentation in being accompanied by the evolution of fœtid and noxious gases.

Putrefaction is characteristic of organic substances, especially of those rich in nitrogen. These become changed either into lower organic compounds or into inorganic compounds, for example, ammonia or sulphuretted hydrogen, or into simple substances, such as hydrogen and nitrogen. Poisonous products are formed by the action of the micro-organisms to which the decomposition of proteids is due, and much labour has been devoted in the last few years to their investigation. The toxic effects are serious if not fatal to many persons who consume food stuffs, especially meat or fish, in which these putrefactive processes are, or have been, active. Their onset may be prevented, or their further

progress may be arrested (1) by keeping the substance in a sterilised vessel from which the air is excluded; (2) by freeing the food from moisture and keeping it perfectly dry; (3) by low temperatures, such as those obtained by cold storage, or below 0° C. (32° F.); (4) by heating to boiling point and hermetically sealing; (5) by the use of antiseptics. (*See* XX. "*Methods of Food Preservation,*" *infra.*)

(*E*) *The Diffusibility of Albumin.*

Place a portion of the egg albumin solution prepared in (*B*) (2) in a dialyser with a small quantity of 10% solution of sodium chloride, suspend the mixture in a large beaker of distilled water for 24 hours (*see page* 25).

Withdraw a small quantity of the water and place the solution in two test tubes (*a*) and (*b*); test:—

(*a*) For the presence of proteid (*pp.* 168-9).

(*b*) For the presence of common salt (*page* 177).

Compare the results in each case with those obtained in IX.—"General Constituents of the Body," III. (*A*) (2), (*page* 166), V. (*B*), (*page* 177).

(*F*) *The Properties of Albumin as seen in raw, lean Meat.*

Extract the albumin from fresh, raw, lean meat by cutting about 29 grams. (1 oz.) into small pieces and immersing them for at least half an hour in just sufficient warm, distilled water to cover them, stirring gently at intervals.

Filter the liquid and divide into four test tubes (*a*), (*b*), (*c*), (*d*). Then proceed to test the characteristics of the filtrate as in (*B*) and (*C*) using the meat juice in the place of egg albumin. Compare the results with those observed when pure or dilute egg albumin were employed.

(*G*) *The Reaction of Albumin to certain Chemical Tests.*

(1) Test some of the egg albumin solution prepared in (*B*) (2) (*a*) for the presence of proteids by the Xanthoproteic and Millon's tests (*page* 168).

(2) Repeat (1), but instead of the albumin use some of the meat juice solution prepared in (*F*).

Note with which test the most characteristic reaction is obtained in each case.

(*H*) *The Properties of Gelatine.*

Examine some gelatine as to colour, texture, consistency and flavour.

Moisten a small quantity with hot water, or partially dissolve it by the application of heat to the vessel in which it is contained. Apply neutral litmus paper to the moist surface and record any change which occurs in the colour of the paper. Is the reaction similar to that obtained in (*A*) (1)?

Add a little gelatine to a test tube three parts full of cold water. Stir gently for some minutes; is there any evidence of change in the gelatine?

NOTE.—Gelatine swells as well as softens under the influence of cold water, but the amount of swelling which takes place depends considerably upon the size of the particles of gelatine subjected to the treatment.

(*J*) *Effect of Temperature upon Gelatine.*

(1) Take two test tubes (*a*) and (*b*). In each place 2 grams of gelatine. To (*a*) add a small quantity of cold water. Stir (*a*) very gently, and set aside for 30 minutes. Pour an equal quantity of boiling water over the contents of (*b*), treat as (*a*), and compare the results in each case with those obtained with albumin in (*B*) (1) and (2).

(2) Put 2 grams of gelatine into a test tube, and heat gently over a Bunsen burner until the gelatine is dissolved, remove from the source of heat and allow the solution to cool. Watch the various changes which occur as the temperature is gradually increased and then as gradually reduced.

NOTE.—It will be observed that gelatine is *softened* by cold water but *dissolves* in boiling liquids, that it *liquefies* with heat but *gelatinizes* again when cooled to a sufficiently low temperature.

(*K*) *The Effects of Acids and Alcohol upon Gelatine.*

(1) Boil some gelatine for several minutes with a 5% solution of hydrochloric acid. Cool; observe that the solution does not "set."

(2) Take three test tubes, (*a*), (*b*), (*c*); half fill each with some liquid gelatine. Add to:—

(*a*) 1 c.c. nitric acid.
(*b*) 2 c.c. pure alcohol.
(*c*) 5 c.c. strong tea, similar to that employed in (*C*) (*c*).

Set aside, and compare the results upon the gelatine after 15 minutes, with those obtained with albumin, (*C*).

NOTE.—The diverse effects of heat and acids upon albumin and gelatine have a direct bearing upon the methods employed in the intelligent cooking of meat, fish and other foods in which both these substances occur; they should also be borne in mind and applied for scullery purposes. For example, it is waste of time to attempt to cleanse an egg whisk upon which some raw egg albumin has dried by plunging it in boiling water, whereas the albumin will gradually dissolve if soaked in cold water; or again, if it be desired to wash the strainer used for making a jelly it will be found that the layer of glutinous gelatine can be easily cleaned off if first softened by soaking in cold water.

(*L*) *Gelatine as a Source of Nutrition for Mico-organisms.*

Dissolve some gelatine in a large test tube, and while slightly liquid, but not too hot (about 26° C., 79° F.) divide it into three portions, (*a*), (*b*), (*c*), and pour into sterilized Petrie dishes.

Allow the gelatine in (*a*) to "set" and expose the surface to the air for 30 minutes; cover, and set aside in a warm, dark place for three days; then examine daily, observing the changes that occur from day to day.

By means of a sterilized pipette add 2 c.c. tap water to (*b*), and 2 c.c. raw meat juice to (*c*); rotate the dishes gently in order to combine the fluids intimately with the liquid gelatine, replace the covers and set aside under conditions similar to those observed with (*a*).

Compare the results in (*a*) and (*b*) with those obtained in "SOME CHARACTERISTICS OF AIR," IV. (*B*) (*page* 54), and "SOME CHARACTERISTICS OF WATER," IV. (*B*), (*page* 72).

NOTE.—It will be seen that, though gelatine when dried is not subject to the putrefactive processes characteristic of fresh albumin, yet nevertheless it provides, when moist, a culture medium for the growth of many forms of moulds and micro-organisms, even in the absence of any albuminous substance such as is added to the nutrient gelatine specially prepared for what are described as "culture" purposes (*page* 40).

The gelatinous character of veal, lamb and brawn thus constitutes an active factor in the special liability to putrefaction of these forms of meat; for gelatine when combined with the albuminous juices of the meat provides a most favourable medium for the rapid growth of micro-organisms.

(*M*) *The reaction of Gelatine to certain Chemical Tests.*

Test some liquefied gelatine for the presence of proteids as directed in "GENERAL CONSTITUENTS OF THE BODY," III. (*pp*. 168-9).

With which of the three tests is the reaction most marked? Compare the results with those given by *albumin*, (1) (*G*), (*pp*. 288-9).

NOTE.—About one-fifth of the body weight consists of proteid matter, it must therefore be supplied in the daily food if physiological equilibrium is to be maintained. The chief duty of nitrogenous (proteid) food-stuffs is to build up the body tissues and keep them in repair, in fact they are indispensable to the carrying on of all the vital phenomena. When their due proportion in the daily diet is very deficient there is debility, anæmia, and greatly diminished power of resistance to the invasion of disease, while their entire absence for more than a limited period ends in death.

The principal sources of this type of food are lean meat, eggs, milk, cheese, fish, poultry, and certain cereals and vegetables (wheat, oats, peas, beans and lentils). As a whole, there is no doubt that proteid of animal origin is more rapidly and perfectly absorbed in the human body than that obtained from vegetable sources.

Gelatine is of little, if any, food value, but it is often described as a "proteid sparer," because when present in articles of diet it apparently economizes the consumption in

the body of more valuable forms of proteid (albuminoids). The delusion, therefore, that any special nutritive value exists in jellied beef tea must be combated, though indirectly the gelatinous matter extracted from bones in the process of soup making contributes to the nutrition of the body in its quality of proteid sparer. Gelatine serves also another purpose, for by its judicious use, foods are frequently made more attractive to the eye or more acceptable to the palate.

Students must be cautioned against two prevalent misunderstandings in respect of proteid food.

(1) That the more expensive cuts of meat or kinds of fish are more nutritious and better absorbed than the cheaper, for all evidence is to the contrary; a fact clearly brought out by the subjoined calculations made by Dr. Hutchison:—

ONE POUND OF PROTEID COSTS:—

	s.	*d.*	
Beef	2	6	
Frozen Mutton ...	2	8 4/5	
Liver, Ox	1	7 3/10	
Heart, Ox	1	9 2/10	
Herring	0	8 45/100	to 5*d.*
American Cheese...	1	6 1/10	
Cheshire „ ...	1	8 4/10	
1*d.* Whole Meal ...	0	8⅓	allowing for 20% loss, 10½*d.*
Fine Flour	1	0 3/10	„ „ 10% „ 1*s.* 1 6/10*d.*
2*d.* Oatmeal... ...	1	2 1/10	
White Bread ...	1	8 4/10	
Hovis „ ...	About same.		
			NET ABSORBED.
Dried Peas, split ...	0	7 1/10	... 20%, 8 9/10*d.*
„ marrowfat	0	9½	... 20%, 11 9/10*d.*
Lentils	0	8 6/10	... 10%, 9 5/10*d.*
Haricot Beans ...	0	8 7/10	... 30%, 1*s.* 4*d.*
Milk	3	4	... practically all.
Eggs	5	1	... practically all.

The public pays to please the palate or the eye, not as it prefers to believe, to increase the nutritive value of its diet.

(2) Cereals and legumes are not a cheap form of proteid for brain workers, on account of the large quantity of material which must be consumed to secure the necessary supply of nitrogen; neither are they cheap when poorly absorbed and consequently wasted as may happen with town-bred children or with those who lead sedentary and indoor lives.

II.—The Properties of Carbohydrates. (A) Starch, (B) Sugar, (C) Cellulose.

MATERIALS: *Starch; ground rice or cornflower; loaf sugar; grape sugar; milk sugar; flour; cake of compressed yeast; potato; turnip; carrot; saliva.*

Carbonate of soda; copper oxide; wood charcoal; caustic potash; liquid malt extract; lime water; iodine solution; Fehling's solution; alcohol; ether; hydrochloric acid; sulphuric acid.

Butter muslin; cotton sheeting; writing paper; filter papers; neutral litmus paper; string; water.

APPARATUS: *Porcelain bowl; beakers; test tubes; flasks; glass rod; glass tubing; pipette; glass slides; funnel; c.c. measure; pestle and mortar; rubber cork with* 1 *hole; rubber bands; tin patty pan; air-oven; thermometer; Bunser burner; dialyser* (*page* 25).

(*A*) *The Properties of Starch.*

(1) (*a*) Examine a little laundry starch as to general appearance, colour, texture, consistency, taste, and smell.

(*b*) Make a cream with starch and cold water. Test with neutral litmus paper. Is the reaction alkaline or acid?

(2) (*a*) *Effects of Heat upon Starch.* Place 10 grams of starch in a porcelain bowl and mix it into a thin paste with cold water. Divide into halves (1) and (2), and place respectively in two test tubes. To (1) add 50 c.c. of cold water, mix thoroughly, and filter carefully through filter paper. To (2) stir in very gradually 50 c.c. of water at 72° C. (162° F.). Continue to stir for some minutes; then set the mixture aside to cool. Notice the various changes brought about by the action of water and heat, and the consistency of the starch in both test tubes at the conclusion of the experiment.

Test the filtrate of (1) with iodine ("PHENOMENA OF LIFE," II., *p.* 16). Compare the result with that obtained by stirring a small piece of the starch jelly made in (2) into 50 c.c. of cold water, and testing in the same way with iodine.

NOTE.—It will be observed that the starch remains practically unchanged by cold water, but the minute grains of which it is composed swell and burst their confining envelopes when combined with hot water. Their contents are thereby released and dissolve, thus forming an opalescent solution, which, if sufficiently concentrated, will gelatinize on cooling. The starch envelopes are formed of a substance called *cellulose*, which is not soluble in water, and causes the turbid appearance characteristic of starch solutions.

(*b*) Heat 20 grams of starch on a small tin patty pan in the air-oven until brown.

Divide into three portions (1) (2) (3), and test as follows for any changes undergone in the baking process. Upon (1) pour hot water, and watch for any signs of swelling, solution, or gelatinisation.

Test (2) with iodine solution.

Test (3) with Fehling's solution. IX., ("GENERAL CONSTITUENTS OF THE BODY," II. (*B*), *page* 174.)

NOTE.—If dry starch be exposed to a high temperature it changes to *dextrine*, a substance intermediate between starch and sugar, which is soluble in cold water. The brown colour of the baked starch indicates a further change of this dextrine into "caramel," familiarly known as "burnt sugar," or "browning." When starch is changed into dextrine (160° C. or 320° F.) it no longer swells and gelatinizes in hot water, but if the heating process be continued after the dextrinized starch has been transferred to a test tube, it will be converted into a black mass consisting almost entirely of carbon.

(3) *Effects of Acid upon Starch.* Take sufficient starch in the form of ground rice or corn-flour to make a thick cream with 20 c.c. of cold water. Drop into it 3 c.c. of 25% sulphuric acid, stirring the mixture cautiously with a glass rod. Place it in a large flask which will hold about a litre (nearly 1 quart) and add 250 c.c. ($\frac{1}{2}$ pint) of warm water.

Heat over a Bunsen flame to 100° C. (212° F.) and keep at this temperature for a quarter of an hour. While the liquid is boiling, withdraw a few drops from time to time with a pipette, and place on white plates or glass slides until cool. Test each separate portion with iodine as follows:—

With a clean pipette drop a small quantity of iodine on to the plates or glass slides by the side of each sample of the boiling mixture, but without touching them. Then, by means of a glass rod, bring the edges of the two liquids gently into contact and observe by the reaction how the samples of starch solution have gradually changed in character as the process of boiling with water and acid has progressed.

Cease boiling when little or no colouration results from testing a sample of the liquid with iodine. Half fill a test tube with the boiled starch solution, cool completely, and then test its character with Fehling's solution. The results will show that it has been converted into a form of sugar called *dextrose* or *grape-sugar*.

NOTE.—The equation for changing gelatinized starch into dextrose is as follows:—

$$\underset{\text{STARCH.}}{3\ C_6H_{10}O_5} + H_2O = \underset{\text{DEXTRINE.}}{C_6H_{10}O_5} + \underset{\text{MALTOSE.}}{C_{12}H_{22}O_{11}}$$

$$C_{12}H_{22}O_{11} + H_2O = 2\ C_6H_{12}O_6$$

When either dextrine or maltose is heated with dilute acid it is converted into dextrose.

Dextrine is characterised by gum-like properties, it is slightly soluble in dilute alcohol, and constitutes a prominent ingredient in the brown crust of a well-baked loaf.

The "port wine" colour observed during the above series of tests indicates the formation of *dextrine*, which intermediate product between starch and sugar is formed by the exposure of starch to a high temperature in (2) (*b*). The addition of dilute acid to the water in (3) facilitates this change at a lower temperature than is otherwise necessary.

(4) *The Diffusibility of Starch.* Fit up a simple dialyser as directed (*page* 25). Fill the head and an inch of the stem of the funnel with thin starch solution. Support the funnel in a beaker of water for some hours. Then test the water surrounding the funnel for the presence of starch (*page* 173).

NOTE.—Starch is a "colloidal substance," *i.e.*, it is not diffusible through a moist membrane. As a rule, non-crystalline bodies are not diffusible, so that starch and similar sub-

stances used by mankind for food must be subjected to some process by which they are transformed into soluble crystalloid bodies before absorption can take place.

(5) *The Action of Unorganized Ferments upon Starch.*

(*a*) *Ptyalin from Saliva.*

(i.) Collect 5 c.c. of saliva from the mouth into a test tube, and mix well with 25 c.c. of cold water. Filter through a filter paper perforated with the point of a pin, and test with neutral litmus paper. If the reaction be acid the solution must be rejected, as any experiments would be vitiated; this precaution must *never* be omitted. If the solution be slightly alkaline add the filtrate to an equal quantity of thin starch solution in a test tube. Keep at a temperature of 37·8° C. (100° F.) in a water-bath for 20 minutes, or until the mixture is clear. Divide the mixture into two portions, and test respectively for the presence of starch and sugar as directed on *pp.* 173-4.

(ii.) To about 20 c.c. of clear, very dilute, starch solution in a large test tube, add 3 c.c. of undiluted saliva, and keep at the body temperature in a water-bath. Support a funnel in a retort-stand above a glass plate, and line the funnel with filter paper. Withdraw small portions of the contents of the test tube at short intervals by means of a pipette, and pass them through the filter. Test the filtrate from each specimen as it drops upon the glass plate with iodine solution as directed in (4).

Observe the gradual change in colour reaction as the experiment proceeds. It will be first blue, then red, then yellow, and finally colourless. The stages are thus indicated of the series of chemical changes as they take place in the solution.

NOTE.—The ferment, *ptyalin*, present in the saliva, begins the process of starch digestion by making it soluble, and then by changing it into a form of sugar, so that it can be readily absorbed by the tissues of the body.

(*b*) *Diastase from Malt.*

(i.) Make about 50 c.c. of starch paste with water at a temperature of 60° C. (140° F.). Add to this 10 c.c. of liquid malt extract, stir, and place the mixture in a water-bath at a temperature of 60° C. (140° F.).

Test portions of the liquid from time to time by withdrawing a drop and bringing it, by means of a glass rod, in contact with a drop of iodine on a glass or china slide. Note how the blue colour, indicative of the presence of starch, is replaced first by *violet* (a mixture of blue and red), then by *red*, which in its turn gradually vanishes, showing that further changes are active. Compare these changes with those occurring when starch is heated with water and acid ((3), *page* 294).

(ii.) When the test fails to give a colour reaction, *i.e.*, indicates that the starch has been changed into maltose, add about 1·5 c.c. (25 drops) dilute sulphuric acid to the remainder of the solution and boil for 10 minutes. Test a portion of this with Fehling's solution (*page* 174), the result will show that *dextrose* has been formed by the combined action of heat and acid upon maltose.

NOTE.—It will be obvious from this examination of the properties of starch that none, as such, could be utilized in the human body, where all substances consumed as food must become soluble in water and so capable of diffusion. It is however a matter of common knowledge that quantities of this apparently insoluble starch are consumed in various forms of food (bread, puddings, cakes, potatoes, rice, etc.), the fact being that it is rendered soluble by the dual processes of cooking and by the transformation effected by the starch-converting ferments present in the saliva and the intestinal juice; these prepare it for absorption by changing it, first into a form of soluble starch and then into the sugar called maltose.

These ferments do not come into activity before about the end of the first year of life, for which reason starchy foods must not be given to infants. It may be also necessary to withhold them in certain forms of disease, where the digestive processes are disordered.

(6) *The presence of Carbon in Starch.* Place some starch in a small porcelain bowl, and heat it over a powerful Bunsen burner. Observe the changes of colour which take place; the starch will become yellow, then brown, then finally black. Prolong the heating process until the black mass takes fire and burns away.

Compare these changes with those which occur in materials known to contain much carbon. Burn, for example, small quantities of wood or paper, compare the ash with the residue from the starch. A close resemblance (except in colour) will be observed also between the ash of coal or coke and that of starch.

(*B*) *The Properties of Sugar.*

(1) *External Characteristics of Sugar.* Examine a lump of cane or beet sugar, as to general appearance, colour, taste, and texture. Compare it with specimens of grape-sugar (dextrose), and milk-sugar (lactose). Moisten the different specimens with water, and test their reaction, whether alkaline or acid, with neutral litmus paper.

(2) *The Solubility of Sugar.* Take three large test tubes (*a*) (*b*) and (*c*), and fill them three parts full of cold water. Add to:—

(*a*) 2 grams of cane-sugar (*sucrose*).

(*b*) 2 grams of grape-sugar (*dextrose, glucose*).

(*c*) 2 grams of milk-sugar (*lactose*).

Note the extent and relative amounts of solubility in each specimen. Bring the contents of the tubes gradually to boiling point by supporting them in the ring of a retort-stand over a Bunsen burner.

NOTE.—Though all sugars are the direct and indirect products of plant life, they are of both vegetable and animal origin and enter into many food-stuffs under various forms. *Sucrose* is found in cane, beet and maple sugar, etc. *Dextrose* (or *glucose*) is found in many fruits and plants, or can be formed from cane-sugar, etc., by boiling with dilute acids. *Lactose* is present in the milk of all mammalian animals.

It will be found that sucrose is most soluble in water and lactose least so.

Sucrose is the sweetest of these sugars and dextrose comes next in order. The absence of sweetness from lactose is one among other reasons why it should be used instead of cane sugar if additional sugar be needed when cow's milk is modified for infants' use; otherwise the palate is unwisely habituated to a cloying sweetness and when the time comes for a more varied diet it rejects forms of food from which cane sugar is absent.

(3) *Effects of Heat upon Sugar.*

(*a*) Add to some hot water at about 80° C. (176° F.) as much cane-sugar as it will dissolve. Put two or three pieces of coarse string into the solution and leave it to cool slowly, when the sugar will be found crystallized round the strings in the familiar form of *sugar-candy.*

(*b*) Place several lumps of cane-sugar in a small, covered porcelain bowl; heat in the air-oven to a temperature of about 180° C. (356° F.). Pour about half of the clear, liquid, melted sugar into a glass vessel and set it aside to cool; a transparent, non-crystalline mass will be formed.

(*c*) Continue to heat the residue in the air-oven to a temperature of at least 200° C. (392° F.). The sugar will become dark brown and viscous, in which form it is known as *caramel.*

Compare the relative solubility of a small quantity of caramel when added to a beaker of water with that of the brittle substance into which the cane-sugar has solidified which was exposed to a lower temperature in (*b*).

NOTE.—It will appear that sugar breaks up into various products when kept for some time just above its melting point. At a higher temperature than this it forms *caramel*, which is a complex mixture of brown products of dehydration, much used for flavouring or colouring food materials. Note the loss of sweetness and the somewhat bitter flavour which accompanies the change from cane-sugar into caramel.

(4) *The Effects of Acids and Alcohol upon Sugar.*

(*a*) Dissolve 10 grams. of cane-sugar in a beaker in 10 c.c. of water. Add 5 c.c. of strong sulphuric acid and stir the mixture very carefully with a glass rod. The black, spongy mass which remains after the sulphurous fumes have been given off is mainly carbon, of which sugar largely consists.

NOTE.—When heated in a closed vessel to the point of decomposition sugar breaks up into a great variety of chemical compounds—carbon, carbon dioxide, water, various acids, tarry matters; a residue of almost pure carbon being left. When heated in free air the same thing happens to some degree, but everything is ultimately oxidised to CO_2 and water, partly by the oxygen contained in the sugar, and partly by the oxygen of the air; a portion of the carbon (the black mass) is the last to burn.

(*b*) Prepare three test tubes (1) (2) (3), and place in each 10 c.c. pure alcohol. Add to:—

(1) 2 grams of cane-sugar.

(2) 2 grams of grape-sugar.

(3) 2 grams of milk-sugar.

Observe the relative solubility of the sugars and compare results with those obtained in (*B*) (2).

NOTE.—*Sucrose* is insoluble, or very slightly soluble in absolute alcohol, but both lactose and dextrose are soluble, especially so if, when alcohol is used to dissolve dextrose, the strength be reduced by the addition of 2 or 3 c.c. of water to every 10 c.c. of alcohol.

(5) *The effects of Heat and Acid combined upon Sugar.*

(*a*) Make a syrup with cane-sugar; place 10 c.c. in a test tube and add twice its volume of Fehling's solution. (IX. "GENERAL CONSTITUENTS OF THE BODY," II., (*B*), *page* 174).

Bring the mixture to boiling point, and observe that no change of colour results as was the case when grape-sugar was used. Again boil the mixture, and maintain this temperature until some change of colour takes place; the change indicates that the combined effect of the heat and acid (the latter present in the Fehling's solution), have altered the character of the sugar.

(*b*) Repeat test (*a*), but use two solutions:—(1) 10 c.c. of honey (grape-sugar) made into a syrup with hot water, and (2) 10 c.c. of a mixture of milk-sugar (lactose) and water. Compare the results in both solutions with those obtained in (*a*), and note the length of time required in each case to secure the reaction characteristic of the presence of grape-sugar.

(*c*) Dissolve 2 grams of cane-sugar in 25 c.c. of water. Put the solution into a flask and add 1 c.c. of strong hydrochloric acid. Support the flask in a beaker of boiling water over a Bunsen burner, and keep at a temperature of 100° C. (212° F.) for about half an hour.

Empty the contents of the flask into a dish, and test with neutral litmus paper. If the reaction be acid, add carbonate of soda in minute quantities, testing with litmus paper after each addition until the solution is just neutral. Then proceed as in (*a*) to test a little of this neutral solution with Fehling's solution for the presence of grape-sugar. The appearance of a red precipitate will show that the character of the cane-sugar is changed by the action of the heat and acid.

NOTE.—The process by which this change is brought about is known as "inversion," and the new form of sugar in which it results is described as *glucose*, which is not so sweet as sucrose. Cooks are familiar with the fact that more sugar is required to sweeten sour or acid fruit in tarts or puddings if cooked *with* the fruit than if it is added when the cooking is completed. The experiments just performed offer the necessary explanation. The cane-sugar, if added to the fruit before cooking, is exposed to the combined action of heat and acid; it becomes "inverted" and changed into bodies less sweet; hence subsequent additions of cane-sugar must be made to compensate for this change.

Sucrose does not reduce Fehling's solution unless the boiling process be prolonged; whereas dextrose and lactose rapidly reduce an alkaline solution of copper sulphate.

The inversion of cane-sugar represents a very remarkable change. It is converted into a mixture of two other sugars, *dextrose* and *levulose*. A similar chemical change is brought about by the digestive ferments in the body, which change is necessary before cane-sugar can be taken into the circulation. Grape and milk-sugars are directly absorbed without this change.

(6) *The Diffusibility of Sugar.*

(*a*) Fit up a dialyser (*page* 25), and fill the head of the funnel and about an inch of the stem with a syrup made with cane-sugar and water, and suspend in a beaker of distilled water for about 24 hours. Withdraw a small quantity of the distilled water with a pipette, and test by taste for the presence of sugar.

(*b*) Repeat the experiment, using dextrose and lactose respectively in place of sucrose for making the solution.

Test for the presence of sugar with Fehling's solution (*page* 174).

NOTE.—In the ready diffusibility of sugars illustrated by this experiment lies an important part of their great value as food-stuffs, as the carbon of which they so largely consist becomes

rapidly available as a source of energy to the body. Hence the instinctively free consumption of sugar, jam, treacle or golden syrup by men employed in very arduous muscular work. It is said that during harvest operations in Canada the reapers pour molasses over every kind of food eaten, in their effort to satisfy this natural craving. Experience has proved that troops march more briskly for greater distances and with less fatigue when preserves and chocolates are served out with liberality.

Sugar would seem to be a food especially adapted to children, because of their great activity. Small organisms also lose more heat in proportion for every kilo of weight than do larger animals, and, on this account as well, children also require, in proportion, more heat units in their food than do adults; but sugar must always be taken with meals, it must not be consumed indiscriminately at all hours and in indefinite quantities. The amount of sugar that may be eaten without bad effects depends much on whether the consumer is leading an active or sedentary life. The food-value of sugar as taken in cakes, pastry, or other cooked foods is probably somewhat modified.

(7) *The Action of Ferments on Sugars.*

Prepare three flasks (*a*) (*b*) (*c*). Add to:—

(*a*) 50 c.c. of a dilute syrup made with loaf-sugar (sucrose) and water, at 30° C. (86° F.).

(*b*) 50 c.c. of a similar preparation of grape-sugar (dextrose) which can be prepared by crushing a few raisins in a mortar with cold water.

(*c*) 50 c.c. of milk-sugar (lactose) prepared as in (*a*).

Stir into each flask about 10 grams of flour. (This addition hastens the results for which the experiment is performed by ensuring an adequate supply of nitrogen to the yeast plants, a slight increase is also made to the amount of sugar into which some of the starch present in the flour is changed by a chemical process.) Add half an ounce of compressed yeast to each flask. Keep at a temperature of about 27° C. (80° F.) for 15 minutes. Then examine each

flask for signs of fermentation, and note in which the yeast is working most vigorously. The quantity of froth apparent on the top of the mixture is an indication of the vigour of the process.

NOTE.—Some authorities recommend that the flour and compressed yeast be thoroughly rubbed up together in a mortar, divided into three portions and combined respectively with the three forms of sugar by rubbing up each combination of yeast flour and syrup in turn in the mortar and then transferring to the flasks.

Fermentation will be found most active in (*b*), where the solid dextrose is split up into two other substances, alcohol and carbon dioxide; the alcohol remains in solution but most of the carbon dioxide gas passes off in the form of bubbles. (XVIII. "*Beverages and their Characteristics*," VI., (*F*) (2) (*b*), *infra*.)

Lactose is hardly capable of being fermented by yeast, neither can cane-sugar be fermented directly, but after being inverted by the *invertase* in yeast, cane-sugar ferments fairly easily. When, however, fermentation is set up in substances present in the same solution as either sucrose or lactose, or if sucrose be converted into glucose by the action of an acid, they are so chemically changed as to become readily fermentable by yeast.

A cake of compressed yeast when in good condition resembles fresh cheese in colour and consistency, being firm and solid; if it be dark-coloured, soft and pasty, it is useless to expect successful experiments. When the whole of a cake is not used it should be well enveloped in tinfoil and stored in a cool, dry place, it will then keep in good condition for a few days.

(8) *The Presence of Carbon in Sugar.*

(*a*) Crush a little cane-sugar and place it in a hard glass test tube. Place the tube in a holder and heat it by moving a Bunsen flame to and fro on the under surface, holding the apparatus in such a manner that the froth which forms as the temperature is raised may not overflow on to the operator's fingers. The black mass which remains is carbon.

(*b*) When dry, crush the lump to a fine powder with a pestle, mix a small portion with about twenty times the quantity of fine copper oxide, and transfer the mixture to a test tube.

(*c*) Fit the test tube with a rubber cork through which passes a glass tube bent twice at right angles; connect the long limb of the glass tube with a beaker containing lime-water. Heat the test tube by moving a Bunsen flame to and fro on its under surface until the turbidity of the water shows that carbon dioxide is being given off (*cf.* "AIR," IV., *page* 53).

(*d*) To prove that pure carbon forms carbon dioxide when heated with copper oxide, perform the following control test:—

Take one gram of wood charcoal and mix it well with fourteen grams of dry, powdered copper oxide, which is a compound of the two elements, copper and oxygen. Transfer to a test tube and proceed as in (*c*). Continue to heat the tube for some time after the white film of chalk has appeared in the lime water, in order to drive off all the carbon dioxide from the mixture. Disconnect the glass tube from the lime water before removing the source of heat, then examine the contents of the test tube, which will be of a dull red colour instead of black as at the beginning of the experiment. The carbon in forming carbon dioxide robbed the copper oxide of its oxygen and reduced it to the metallic state in which it now appears.

NOTE.—If any organic substance be heated with copper oxide the carbon of the organic matter unites with the oxygen of the copper compound and forms carbon dioxide.

Though sugar constitutes a very important source of heat and energy to the body, and is also a food-stuff of great value owing to the rapidity with which it is absorbed; it is calculated that not more than 10 grams of sugar are normally

present in the whole blood supply (5 litres) of an adult man (*Fig.* 60). The bulk of sugar absorbed from the various food stuffs of which it forms a constituent is immediately turned to account as a source of heat for the maintenance of the vital processes and for the many forms of muscular movement ever active in a healthy body. That is to say, the carbon unites with the oxygen of the blood when absorbed into the circulatory system, and as a consequence of the resulting oxidation process becomes finally changed into carbon dioxide and water, in one or other of which forms it is excreted from the body.

The small proportion of the sugar consumed which is not required for this immediate use in the body is stored up in the form of *glycogen* (a colloid carbohydrate), in the liver and muscles, while any remainder appears to be converted into fat.

There are grounds for assuming that if the consumption of sugar by the tissues be increased in consequence of extra work and heat production, so that the reserve of glycogen proves insufficient to meet the body's needs, fat can be converted into sugar, probably in the liver, from whence it is transferred to the blood stream. In the opinions of some physiological chemists, sugar can also be formed from proteids, so important it appears is an adequate supply of carbon to maintain the heat and energy associated with animal activity.

(*C*) *The Properties of Cellulose.*

(1) *Various forms of Cellulose.*

(*a*) Take two or three samples of paper, such as ordinary writing and filter paper; moisten with water and test with iodine. Does the result justify the statement that cellulose is not a typical carbohydrate?

(*b*) Shred up some cotton sheeting in water, test in the same way for the presence of starchy substance. Steep the cotton sheeting in cold concentrated sulphuric acid for some minutes; dilute very freely, BUT CAUTIOUSLY, with water. Then repeat the test for starch; the iodine will now give the characteristic reaction.

NOTE.—Cellulose is not coloured by the action of iodine unless previously treated with strong sulphuric acid.

(2) Take three beakers (*a*), (*b*), (*c*), and cover the open end of each with a piece of clean butter muslin held in position by means of a rubber band, it should sag slightly in the centre. Grate into:—

(*a*) Some raw potatoe.

(*b*) Some raw turnip.

(*c*) Some raw carrot.

Let the pulp fall in each case from the grater into the butter muslin.

Remove the muslin from (*a*), (*b*), and (*c*), fold it in each case well over the grated pulp, and press out as much as possible of the watery juice into the respective beakers, by squeezing with the fingers or pressing with a glass rod against the side of the beaker.

Examine the woody fibre left in the muslin wrappers after the pressing and straining process has been completed, and observe how impossible it is to separate this fibrous substance, *cellulose*, from the starch and sugar contained in the cells of which it forms the confining envelopes.

To illustrate this fact take six test tubes, $(a)^1$, $(a)^2$, $(b)^1$, $(b)^2$, $(c)^1$, $(c)^2$, add to:—

$(a)^1$ 5 c.c. of the filtrate from (*a*).

$(a)^2$ A small quantity of the fibrous residue from (*a*) diluted with cold water.

$(b)^1$ 5 c.c. of filtrate from (*b*).

$(b)^2$ A small quantity of the residue from (*b*) diluted as directed in $(a)^2$.

$(c)^1$ 5 c.c. of the filtrate from (*c*).

$(c)^2$ A small quantity of the residue from (*c*) diluted as directed in $(a)^2$.

Test the first and second group for starch (*page* 173) and the third group for sugar (*page* 174).

The results will show the presence of starch or sugar respectively in each group, in spite of the efforts made to separate the more soluble substances from the insoluble cellulose.

NOTE.—The membranous partitions, skins and shells of fruit are formed of cellulose and it is within cellulose walls that the nutritive principles of plants are contained, whether proteid, carbohydrate or fat. It is a substance insoluble in water, and in its matured condition it is refractory to all agents except strong acids and caustic alkalies; it can however be softened by cooking. Under the influence of heat and moisture, the intercellular substances, which bind the cell walls together, are apparently dissolved, and thus permit of the mechanical rupture of the cell walls themselves, either during the cooking process or by the pressure exerted during mastication.

Cellulose has therefore small claims to be classed as a food-stuff, for even that present in very young and tender plants can be but slightly digested by human beings, though, probably in consequence of some fermentative action, the epithelial cells of the intestine seem able to dissolve a certain small proportion of the cellulose consumed with food. Investigation shows that about 25 % of the tender, woody fibres of lettuce disappear in the digestive canal, and from 47 % to 62 % of the cellulose present in carrots, celery and cabbage.

The claims of cellulose therefore to be included in a study of food principles rest on other than nutritive grounds. They are based on the really important function it exercises in furnishing the required bulk of food essential on account of the mechanical stimulus it affords to the intestines, and its consequent value in the promotion of healthy peristaltic activity. Where the diet consists largely of substances such as eggs, milk or meat, which can be, and usually are, almost entirely absorbed in the process of digestion, the solid excretory products from other articles of diet are liable, in the absence of sufficient bulk of undigested residue to stimulate peristalsis, to accumulate in the intestines. By their decomposition, together with the re-absorption of the products of this decomposition into the blood stream, a condition of self-poisoning (auto-intoxication) is set up, which seriously interferes with health.

For this reason whole-meal bread and increased amounts of fruit and vegetables, all of which contain high percentages of cellulose, are recommended to sufferers from constipation, with the express object of stimulating the activity of the intestines by increasing the bulk of undigested residue. The slight degree of irritability thus excited results in more forcible muscular contractions, and consequently in a more complete and rapid expulsion of the products of digestion.

On the other hand, it is an excess of cellulose in the dietary which constitutes one of the chief objections to vegetarianism, for the daily dietary requirements of proteid, carbohydrates and fat can only be met by the consumption of very large quantities of vegetables and fruits, thus seriously taxing the digestive organs which, in man, are not adapted for dealing with such masses of food as require long periods for their digestion. Comparative anatomy demonstrates that the human digestive system is designed for a *mixed diet*, in which the important nitrogenous elements can be derived from the more concentrated and usually more digestible forms of animal proteid foods, such as meat, fish, milk, eggs or cheese (*Fig.* 62).

The irritating effects of a diet rich in cellulose, whereby food is often hurried through the intestine and excreted before all its nutritive properties have been absorbed is advanced by some authorities as a reason why wholemeal bread and oatmeal porridge are rejected as articles of daily diet by the poorer classes of the community. To such people it is of great moment to extract every particle of nourishment from their limited supply of food and they cannot afford the dietary extravagances possible to their richer brethren.

Chemical analysis does indeed emphasise the high proportion of nitrogen present in whole-wheat meal, oatmeal, peas, beans, and lentils, but physiological investigations afford reliable evidence that man is nourished by what he assimilates, not by what he eats. There is no doubt that the cellulose envelopes of vegetable cells containing proteid matter offer serious obstacles to the digestive powers of sedentary workers, to dwellers in towns, to the debilitated and to the sick, unless the food of which they form a part be consumed in small quantities, after prolonged and skilful cooking, and in conjunction with other more easily digested substances.

III.—The Properties of Fat.

MATERIALS: *Butter; lard; suet; olive oil; tallow; alcohol; bicarbonate of soda; caustic soda or caustic potash; neutral litmus paper; water.*

APPARATUS: *Small flasks; beakers; test tubes; thermometers; glass rods; china bowls; small porcelain dishes; 3 corks with large holes; sharp knife; sand-bath; Bunsen burner.*

(*A*) Take small quantities of fresh butter, lard, suet and olive oil. Compare their appearance, smell, consistency, and flavour.

Test their reaction on neutral litmus paper. For this purpose place a small quantity of each specimen of fat in a clean, dry test tube; add 5 c.c. alcohol and heat until the fat melts; then test with very sensitive litmus paper.

NOTE.—The fats employed in domestic life have been described as simply solidified oils, and oils in their turn have been described as liquid fats. In the body, all forms of fat are semifluid or fluid. The most important fats used as foods are *olein* and *palmitin*, present in both animal and vegetable substances, and *stearin* which is an animal fat alone. *Olein* is fluid at the ordinary atmospheric temperature (*e.g.*, olive oil), and contributes to the softness of bacon fats; it is the chief constituent of animal fats and is present also in most vegetable fats. *Stearin* is the hardest form of fat and predominates in mutton suet. Beef fat is an example of palmitin, which is always solid below 45° C. (113° F.).

It will therefore be seen that to the proportion of each kind of fat present, suet, lard and butter owe their relative hardness, softness and mean melting points. To the fats of volatile fatty acids present in milk (*butyrin*, *caprin*, *caproin*, etc.) butter owes much of its delicate and appetising flavour. When fats are pure they are neutral bodies, colourless and tasteless.

(*B*) *The Effect of Heat on Fat.*

(1) Take small quantities of the fats used in (*A*), but cut the lard and suet into small pieces. Arrange four porcelain bowls (*a*) (*b*) (*c*) (*d*), on a sand-bath over a Bunsen burner, and half-fill each with water. Add a small quantity to:—

(*a*) of butter; (*c*) of suet;
(*b*) of lard; (*d*) of oil.

Stir the contents of each basin with a glass rod (using a separate rod for each) as the temperature of the water rises, and when it reaches boiling point, continue the boiling and stirring for several minutes, in order to observe the changes which take place on exposure of the different forms of fat to high temperatures.

(2) (i.) Take three small beakers (*a*) (*b*) (*c*), and half fill each with cold water.

Arrange (*a*) upon a sand-bath over a Bunsen burner and add slowly several small pieces of butter. Stir continuously and gently with a thermometer, and notice the point at which the butter melts. Remove the beaker from the sand-bath, and place it in a large vessel of cold water to cool. Watch carefully, and notice the temperature at which the butter solidifies.

Repeat the process with small pieces of lard or bacon fat in (*b*) and with suet in (*c*). Record and compare the temperatures at which each form of fat melts and solidifies.

(ii.) Or, half fill three small flasks with lard, olive oil and tallow, liquefying the lard and tallow for the purpose by heating about 60 c.c. (2 oz.) of each fat in a large test tube. Pass three thermometers through three corks and close the bottles with the corks in such a way that the bulb of each thermometer is well embedded in the lard, olive oil or tallow. Cool the flasks until their contents become solid, lay the flasks in a horizontal position upon a warm sand-bath. Heat the sand-bath very gently and closely observe the temperature registered by each thermometer as the fat in the flask in which it is fitted becomes just liquid. This is the melting point.

(3) Take four small porcelain dishes (*a*) (*b*) (*c*) (*d*). Place in :—

(*a*) some butter; (*c*) some suet;

(*b*) some lard; (*d*) some olive oil.

Heat gradually on a sand-bath over a Bunsen burner. Observe the odours and other evidences of change which accompany the exposure of fats to a high temperature.

NOTE.—Fat is generally less easily digested than starch, butter being the form in which it is best assimilated. As is the case with proteids, animal fats are more generally digestible than are vegetable.

Olein melts at 5° C. (41° F.), *palmitin* melts at 45° C. (113° F.), and *stearin* at from 50° to 66° C. (128° to 150° F.). It is thus olein which holds the other two forms of fat dissolved at body temperature.

Fats are all soluble in hot alcohol, ether and chloroform, but are insoluble in water. It will be observed that each fat melts at a lower temperature than that of boiling water.

The order of digestibility of fats is practically the reverse of that of their solidification. The fat which solidifies most easily after cooking is the least digestible. Neutral fats eaten in their natural condition are usually digested and readily absorbed, but when they are decomposed by exposure to very high temperatures, their products become irritants. Fats may be heated to a temperature far above 100° C. (212° F.) without showing any change, but there comes a point, different for each fat, where reaction takes place, the products of which irritate the mucous membranes and thus interfere with digestion. It is the volatile products of such decomposition which cause, not alone, the familiar action upon eyes and throat during the process of frying, but also tell-tale odours throughout the house, or in the case of fried-fish shops, throughout the neighbourhood. The smell of the cotton-seed oil usually employed by cheap fried-fish shops is specially acrid and objectionable. It constitutes a "nuisance" unless measures be taken to carry off the fumes.

It becomes evident therefore that the indigestibility of fatty foods, or of foods cooked in fat, is chiefly due to the harmful substances produced by the high temperature to which they are exposed during the process of cooking.

(*C*) *The Emulsification and Saponification of Fats.*

(1) (*a*) Take three test tubes (i.) (ii.) (iii.). Add to (i.) 5 c.c. olive oil, and an equal amount of cold water. Place the thumb over the end of the test tube, and

shake the contents vigorously. Note the appearance of the mixture, and stand the test tube aside for 15 minutes.

Melt a small quantity of lard in (ii.), and add an equal quantity of water. Shake, and compare the results with (i.).

(*b*) After 15 minutes add a pinch of carbonate of soda to the contents of each test tube before subjecting them to further shaking. Again set both aside for 15 minutes, and notice the more permanent emulsification which results.

(*c*) Half fill (iii.) with water and raise it to the boiling point; stir in a little finely-shredded suet or lard, add a few drops of a strong solution of caustic soda or caustic potash and continue to stir for a short time. Notice that the fat disappears, while the mixture becomes more or less milky and forms a permanent emulsion on cooling.

(2) To demonstrate the process of saponification, that is, the decomposition by heat of neutral fat into fatty acid and glycerine, place about 50 c.c. of a solution of caustic soda made with alcohol (instead of water), in a small flask, and heat it gently in a water-bath over a Bunsen burner. The boiling point is low, and must not be reached at this stage of the experiment.

Melt about 10 grams of lard or suet in a small porcelain dish. Hold a glass rod over the mouth of the flask and drop the melted fat gently down the rod into the flask, shaking the latter at frequent intervals during the process, or stirring its contents vigorously with a glass rod. After all the fat has been added continue heating until the alcoholic solution reaches its boiling point.

V

Then test the contents of the flask as follows, to see if the process of decomposition is accomplished. Drop some of the solution from the flask into a test tube containing about 10 c.c. of cold distilled water. The formation of a clear solution, and the absence of oil globules on the surface of the liquid, will indicate that saponification is complete; until this occurs, the heating and stirring process must be continued.

NOTE.—From a chemical point of view fats are "salts," being composed of a base, glycerine, and an acid, which in the case of the most familiar fats is either *palmitic*, *stearic* or *oleic* acid respectively.

If a neutral fat be boiled with a caustic alkali it is split up into its constituents, glycerine is set free and the fatty acid unites with the alkali to form a soap.

It is necessary to use an alcoholic solution of caustic soda or potash, as the stearic acid present in suet and lard is insoluble in water, but as has been already mentioned it is soluble in either alcohol or ether.

In fats are found the greatest source of heat to the body, and consequently of energy, but sometimes they also assist, indirectly, in the building-up of the tissues by protecting proteid substances from decomposition or oxidation. Fats are poorer in oxygen than carbohydrates but richer in carbon and hydrogen, their heat equivalent being much greater; indeed it is double that of the former. They are usually even more completely absorbed than proteids and may replace carbohydrates or be themselves replaced by proteids. The process of fat digestion is effected in the small intestines by the action of certain ferments, especially *steapsin*, which is a fat-splitting ferment present in the pancreatic juice. Much the same sort of reaction occurs as in the process of saponification.

Fats also undergo a physical change in the body, that of *emulsification*, when the small globules into which the fat is broken up give a milk-like appearance to the product of this phase of digestion. If consumed in excess, fats may be excreted unaltered, but if deficient in quantity the whole nutrition of the body suffers, even though the other proximate principles of the body be present in abundance in the food.

The absence of fat from most fruits, cereals and roots, and its poorly assimilable form when present in them, has been suggested as a possible cause why an exclusively vegetable diet proves insufficient to maintain a high standard of health.

The exact amount of fat required daily varies considerably; it is relatively high in infancy and childhood, then remains fairly constant through maturity, diminishing with old age (*Fig.* 61). The quantity consumed is much influenced by climatic conditions, age, sex, class of occupation, and the form in which the fat itself is taken. It is a costly food compared with carbohydrates, which are consequently largely employed as substitutes, though they cannot entirely replace the functions of fat in the body. It is advisable, therefore, in the interests of health, especially the health of children, to advocate the much more general introduction of dripping, margarine and suet into the dietary of the poorer classes, to whom cream and butter are over costly luxuries, but to whose health the adequate representation of fat in their diet is a matter of primary importance.

XV.—ELEMENTARY STUDY OF PROXIMATE FOOD-PRINCIPLES IN MILK, EGG, CHEESE, FISH, FLOUR, BREAD, VEGETABLES, AND FRUITS.

I.—To show the presence of proximate Food Principles in Milk (*Fig.* 68, *page* 327.)

MATERIALS: *Fresh milk; hydrochloric acid;* 1% *solution of osmic acid;* 2% *acetic acid; ammonium oxalate; ammonium molybdate; barium chloride; nitric acid; silver nitrate; methylated spirit; benzine; ether; alcohol; vinegar.*

Butter muslin; rubber bands; blotting, tissue and filter paper; red, blue and neutral litmus paper; turmeric paper; water.

APPARATUS: *Beakers; test tubes; pipette; glass funnel; flasks; tall glass jar; watch glass; slips of glass; glass rod; thermometer; flat dishes; sand-bath; retort-stand; Bunsen burner.*

(*A*) *Nitrogenous Substances.* (*Proteids.*)

(1) (*a*) Heat 250 c.c. (½ pint) of fresh milk to about 55° C. (130° F.) in a beaker.

Remove the scum which floats on the surface from the liquid beneath; divide the hot milk into two portions (*a*) and (*b*); test them for the presence of proteid matter, (*a*) by the Biuret test and (*b*) with Millon's reagent. Record with which test the best results are gained. ("GENERAL CONSTITUENTS OF THE BODY," IX., III. (*B*) (1) (*a*), *pages* 168-9.)

(*b*) Dilute 25 c.c. of the hot milk with an equal volume of water, and place in a test tube. Add a few drops of vinegar, and observe that a slight precipitate is formed. Gently warm the liquid in a water-bath but do not let it reach the boiling point.

When warm, strain it through butter muslin into another test tube. Divide the solid residue left on the muslin into three portions, and test each for the presence of proteid matter as directed (*pages* 168-9).

(*c*) Boil some of the clear filtrate in a second test tube with a view to detecting the presence of albumin, which will be indicated if any coagulation results, (*page* 167) (*cf.* also XVII. "A STUDY OF MILK," I., (*L*), *Note, vide infra*).

NOTE.—The scum which forms on the surface in (1) is largely *fat*, *casein* and *lactalbumin*, and occurs in consequence of rapid evaporation at that point. The precipitate observed in (2) consists mainly of *casein*.

(2) *Alternative Method* (*I.*).

(*a*) Take 200 c.c. of fresh milk. Warm on a sand-bath to 50° C. (122° F.).

(*b*) Drop in hydrochloric acid cautiously from a pipette and stir gently and steadily with a glass rod until the milk curdles into a thick mass. The liquid part is called "whey."

(*c*) Make a strainer by stretching a double thickness of muslin over a glass beaker so as to "sag" a little in the middle, and hold it in position with a rubber band. Separate the curd from the liquid by filtration through this strainer.

(*d*) Then separate the curd from the muslin by washing it in a beaker with methylated spirit, breaking up the lumps with a glass rod in order to extract any remaining water.

Dry the curd, by placing it (i.) between sheets of blotting or filter paper and squeezing gently; (ii.) by exposure to the air on a flat dish in order to allow the spirit to evaporate. When dry, transfer it to a small glass beaker, and add sufficient ether or benzine to cover it, then beat it up well with a glass rod to wash out any fat present.

Pour the mixture through a glass funnel on to a large flat dish or plate and set it aside, well away from any lighted gas or lamp, until the ether or benzine has evaporated.

Again dry the curd on blotting paper.

(*e*) Then place some of the prepared curd in a test tube and test for proteid by the xanthoproteic reaction (*page* 168).

(3) *Alternative Method* (*II.*).

Place 10 c.c. of fresh milk in a small flask with the addition of 30 c.c. distilled water. Then with great care add, drop by drop, a small quantity of 2% acetic acid. A finely divided white precipitate forms slowly, and gradually settles to the bottom of the liquid. When the precipitate (composed of precipitated *caseinogen* and *fat*) has all been

carried down, filter the fluid into a test tube and employ both the solid residue and the filtrate for the following tests.

NOTE.—Great care is necessary to bring off this treatment successfully, the addition of one or two drops too much of the acid will spoil the experiment.

(*a*) Test 5 c.c. of the filtrate in a test tube with Millon's reagent (*page* 168). Note the characteristic brick-red colour which appears on heating.

(*b*) Test a portion of the solid precipitate with the same reagent and compare the results with those obtained with the filtrate in (*a*).

(*c*) Boil 5 c.c. of the filtrate and observe any indications of the presence of albumin (*page* 167).

NOTE.—The insoluble proteid substance formed in milk by the action of rennet (a ferment present in the digestive juice of the stomach) is known as *casein*. Apparently its constituents exist in fresh milk in the soluble form of a compound of albumin and calcium phosphate. Casein is also precipitated by lactic acid (a product of milk sugar developed during the "souring" of milk, a process itself the result of certain acid-forming bacteria), and by mineral acids. According to most recent authorities the proportion of albumin to caseinogen in cow's milk is about one-fifth. Thus the proteids of milk contain about 15% of lactalbumin which is soluble, but which is coagulated at a temperature of 65° to 73° C. (149° to 163° F.), when it forms with a few minor ingredients the "skin" on boiled milk. Caseinogen, on the other hand, constitutes about 80% of milk proteids, does not coagulate with heat, but is coagulated by acids, which break up the combination previously existing between the caseinogen and calcium phosphate, the former being converted into casein, of which the characteristic milk-clot is formed.

(*B*) *Carbohydrates.*

Take some of the "whey" separated by filtration from the curd made in (*A*) (2) (*b*) and pass again through moist filter paper until quite clear.

Place 10 c.c. of the filtrate in a test tube and boil it in order to precipitate the lactalbumin; filter, and test for the presence of *lactose* with Fehling's solution (*page* 174).

NOTE.—Milk-sugar or lactose is the principal carbohydrate of milk. The sugar acts as a reducing agent upon the Fehling's solution as appears by the formation of the orange precipitate of cuprous oxide.

(*C*) *Fats.*

(1) (*a*) Shake up 5 c.c. of fresh milk with 5 c.c. of benzine or ether in a test tube, and set aside until a layer of fat and its extractives have formed on the surface of the milk. Draw off this layer with a pipette and drop it on to a clean watch-glass; the residue, after evaporation of the benzine or ether, is practically pure fat (cream).

(*b*) Leave 500 c.c. (1 pint) of fresh milk to stand for some hours in a tall glass jar. Note that it has separated into two distinct layers, the upper one being deeper in colour, thicker in consistency, and relatively much smaller in proportion to the whole quantity. Remove two or three drops of the top layer with a pipette and place it on tissue paper or on a slip of clean glass. Set aside to dry. Notice the evidence of the presence of fat by the greasy stain left on the paper or the glass.

(*c*) Take the solid residue left on the filter paper in (*A*) *Alternative Method* (*II.*) (*c*). Wash it first with water and then with alcohol, finally combine it with a mixture of ether and alcohol. Filter this mixture and evaporate some of the clean filtrate, one portion on a slip of clean glass and a second on a pad of filter paper. Notice the greasy residue of butter fat in each specimen.

(2) Mix 5 c.c. of the cream with 5 c.c. of benzine in a test tube. Shake well together and filter.

Allow a drop of the filtrate to fall on a clean glass slide or on a piece of filter paper. Again observe the indications of fat after the benzine has

evaporated. Repeat the experiment with 5 c.c. of fresh, whole milk and compare the evidence of the presence of fat.

NOTE.—Better results will be obtained if two drops of 20% caustic potash be added before mixing either the cream or the milk with the benzine. By adding an alkali, a certain amount of caseinogen is changed in its physical condition, so that the caseinogen molecules, which lie between and thereby hold apart the fat globules, are diminished in number and consequently the fat globules are more readily dissolved by the benzine.

(3) Withdraw 5 c.c. of cream from the vessel in (1) by means of a pipette and place it in a test tube. Add one or two drops of 1% solution of osmic acid (*page* 175). Repeat the test with whole milk instead of cream. Does any difference in the degree of reaction to this test confirm your knowledge of the very different proportions of fat present in cream and in even the richest milk?

(*D*) *Salts.*

Take four test tubes (*a*), (*b*), (*c*), (*d*), and put in each of (*a*), (*c*) and (*d*) 5 c.c. of the filtrate prepared in (*A*) (2), and in (*b*) not more than a few drops of the sample to be tested. Add to:—

(*a*) A few drops of a solution of ammonium oxalate. The fine, white, floury precipitate which forms consists of lime salts.

(*b*) 10 c.c. of a solution of ammonium molybdate; heat the mixture gently by waving the test tube to and fro in the flame of a Bunsen burner, bearing in mind the directions given on *page* 178. The pale, greenish-yellow, cloudy precipitate proves that phosphates are present.

(*c*) A few drops of hydrochloric acid, followed by 5 c.c. of a solution of barium chloride. If a white crystalline precipitate forms, it demonstrates the presence of sulphates, but the amount present in milk is so small that conclusive results will probably not be obtained.

(*d*) Acidulate (*d*) with a few drops of nitric acid, then add a few drops of a solution of silver nitrate. The white, curdy precipitate consists of chlorides.

NOTE.—When ammonium oxalate is added to a neutral or alkaline solution of any calcium salt a chemical reaction takes place, and a very fine, white precipitate of calcium oxalate is formed. The precipitate in (*b*) *cannot* be formed in the absence of phosphorus. The addition of the hydrochloric acid to (*c*) leaves any precipitate of barium sulphate insoluble if the amount present be sufficient for detection. As the nitric acid used to acidulate the filtrate in (*d*) contains no chlorine, it follows that if a thick curdy precipitate accompany the introduction of silver nitrate, which also contains no chlorides, it must have been derived from the specimen tested.

The fact that milk contains representatives of each of the proximate food principles places it in a very unique position, and is liable also to give rise to a certain amount of misconception as to its value as a food stuff at different periods of life (*Fig.* 61, *page* 280. *Fig.* 63, *page* 327).

Milk constitutes a "perfect" food only during the early weeks or months of the existence of young mammals when received by them direct from their mothers, in which case if the mother be healthy it contains the exact amount of each nutritive principle required from day to day by the young, growing organism, in the form best adapted to its powers of assimilation. It is also of great value for dietetic purposes throughout childhood, especially where economy is of importance, while in disease no other form of nutriment can replace milk.

It is nevertheless advisable to draw attention to the conditions Dr. Hutchison has enumerated which must be fulfilled by a "perfect food," and the proofs he has advanced that cow's milk fails to comply with these when used exclusively for dietetic purposes by the healthy adult.

A perfect food, he writes, must:—

"(1) Contain all the nutritive constituents required by the body: proteids, fats, carbohydrates, mineral matter and water.

"(2) Contain these in their proper relative proportions.

"(3) Contain the total amount of nourishment required daily in a moderate compass.

"(4) The nutritive elements must be capable of easy absorption, and yet leave a certain *bulk* of unabsorbed matter to act as intestinal ballast.

"(5) It must be obtainable at a moderate cost.

"On examining *the claims of milk to be regarded as a perfect food*, one finds that it only conforms to the first of the conditions above laid down.

"It does indeed contain representatives of all the nutritive constituents required by the body, but it does not contain them in proper relative proportion. Relatively, it is too rich in proteid and fat and too poor in carbohydrate to be a perfect food. In order to obtain the requisite 3,000 calories of energy daily one would require to consume about 8 pints of milk, and that would contain about 140 grammes of proteid, while 125 is all that is necessary. An excess of proteid and fat is essential in the case of infants, where the body substance is being added to by growth and where a large supply of fuel is needed, but it is not necessary for adults. Milk, in fact, is a food for babes, not for men.

"Further, milk is much too bulky to be a perfect food. In the matter of ballast, also, milk is deficient. Lastly, milk is too expensive to be a perfect food. To live on it alone would cost about 1*s*. 6*d*. a day. An ordinary mixed diet can be obtained for less than a shilling." (*"Food and the Principles of Dietetics," Chap. VII., Robert Hutchison, M.D., Arnold, London.*)

Cow's milk of a good average quality should have about the following chemical composition, though to some extent variations in composition cannot be obviated; they depend on the breed and age of the cows, upon their feed, upon the period which has elapsed since calving, upon whether the specimen of milk examined was taken from the mixed milk of many cows, and finally whether it was drawn during the first part of the milking process (fore-milk), when the fat percentage is low, during the middle period, when the composition is average, or towards the conclusion, when the "strippings" are richest in fat:—

Water	87 to 88	per cent.
Proteids	3 to 3·5	,,
Sugar	4 to 5	,,
Fat	3·5 to 4·5	,,
Salts	0·7	,,

II.—To show the Presence of Proximate Food Principles in Egg (*Fig.* 64, *page* 327).

Materials: *Eggs; powdered chalk; ether;* 10% *solution of sodium chloride;* 1% *solution of osmic acid;* 2% *acetic acid; lime water; litmus paper; filter paper; salt; distilled water. Millon's and the Biuret tests* (*pp.* 168-9).

Apparatus: *Test tubes; beaker; small porcelain basins; wide-mouthed, stoppered bottle; evaporating dish; pestle and mortar; platinum wire; small cork; air-oven: retort stand; sand-bath; Bunsen burner.*

(*A*) *Nitrogenous Substances.* (*Proteids*).

(1) Carefully separate the yolk of a raw egg from all traces of white, by turning the yolk rapidly from one part of the broken shell to the other, meanwhile allowing the white to flow out into a small porcelain basin.

Pour half of the yolk into a large test tube and add twice the quantity of ether; cork the tube and shake vigorously. Set the tube aside until the contents of the tube have separated into layers; then carefully pour off the yellow liquid, which forms above a thick yellowish mass at the bottom of the tube, and reserve for subsequent use.

Repeat the washing process, by the addition of small quantities of ether, until nothing is left but a thick white mass, from which all the fatty matters (present in the yolk in a condition of emulsion), have now been extracted. Add the liquid poured off after each washing to the ether solution obtained from the first washing.

(2) Divide some of the residue reserved in (1) into two portions (*a*) and (*b*) and dissolve (*a*) by immersing and stirring it in water; filter and divide the filtrate into two portions (i.) and (ii.).

Test each for the presence of proteids (i.) by Millon's and (ii.) by the Biuret test respectively (*pp.* 168-9). Repeat with (*b*), but use a solution of 10% sodium chloride in place of water.

NOTE.—The extraction with ether must be repeated several times and very vigorously until all the yellow colour is gone from the egg yolk. Benzine must not be substituted for ether as it emulsifies the yolk of egg so completely that extraction becomes impossible. It takes some time to get a good result (from 3 to 4 hours), owing to the high percentage of fat (33·3%) which it is desirable to extract before subjecting the yolk to the tests for proteids, of which the amount present (15·7%) is less than half the proportion of fat. The accompanying decolourization also contributes to the ease with which the characteristic proteid reactions can be observed. A white precipitate will form in (*a*) (i.), which will turn brick-red on boiling; there will be no reaction to the Biuret test in (*a*) (ii.); this will, however, give a faint violet colour when applied to (*b*) (ii.), while no change of colour will follow boiling in (*b*) (i.).

(3) Take a few c.c. of white of egg, cut it well with scissors and place a small portion in a wide-mouthed, stoppered bottle.

Add 20 volumes of filtered water, shake until it froths and invert over a beaker of water.

When the froth and proteid particles float to the surface, carefully withdraw the stopper and allow some of the mixture to mix with the water in the beaker, the liquid will probably be opalescent, due to globulin; if strongly opalescent filter through two layers of butter muslin.

Test the fluid or filtrate with litmus paper, if alkaline neutralize with acetic acid (2%). Add Millon's reagent to a small portion of this solution, a white precipitate will form which will turn red on boiling.

(*B*) *To show the presence of Carbon.*

Boil an egg hard; cool and separate the shell, detach the white from the yolk, and chop the white into fine particles. Place a small quantity of the chopped white in a porcelain basin and dry it partially by prolonged exposure (4 days) in an air-oven, at a temperature of about 60° C. (140° F.). Grind the dried egg albumin to a fine powder in a mortar, and then heat it in a small porcelain dish at a high

temperature in the air-oven, or in a covered dish on the sand-bath above a Bunsen burner, until it becomes black, a change due to the liberation of carbon. Prove this statement by treating a portion of the carbonized albumin as directed in "THE PROPERTIES OF CARBOHYDRATES," (*B*) (8) (*d*) (*e*). Reserve the remainder for use in (*D*).

NOTE.—Only a very small quantity of lime-water is necessary to show the presence of carbonic acid gas, about 15 c.c.

(*C*) *Fats.*

(1) Evaporate the combined ether extracts reserved from (*A*) (1) over a warm water or a sand-bath. (*Remember the highly inflammable nature of the liquid*). The yellow, semi-fluid, oily residue is similar to melted butter. Allow a drop or two of this residue to fall on filter paper and a similar quantity upon the surface of a beaker of water; observe the characteristic evidence of fat in each case.

(2) Take a small portion of the hard boiled yolk of egg of which the white was used in (*A*) (3), pound in a mortar, place in a small porcelain basin and add a few drops of 1% solution of osmic acid. Observe the strong, immediate indication of the presence of fat. ("GENERAL CONSTITUENTS OF THE BODY," IV. (*C*), *page* 175).

(*D*) *Salts.*

(1) Drop some raw egg albumin into an evaporating dish and place in the hot air-oven until the albumin is dried into a brown, brittle mass, as directed in (*B*).

Take the platinum wire, fix it round a piece of this substance and bring it in contact with the outer edge of a Bunsen flame. Observe the yellow flame, which indicates the presence of sodium. Now dip the wire into a small quantity of dilute hydrochloric acid and again bring it in contact with the Bunsen flame; a momentary flash of red light will indicate the presence of calcium. Confirm this test by thoroughly mixing a little common salt with powdered chalk. Rub the clean platinum wire in this mixture, after dipping it in distilled water, and expose to the flame of a Bunsen burner as above (*page* 177).

(2) Take the remainder of the hard boiled yolk of egg prepared in (*B*) and dry in the air-oven in the same way as directed for the white. When dried to a slightly brown colour and crisp consistency, proceed as in (1) to demonstrate the presence of sodium, calcium, and potassium salts by the flame test.

NOTE.—The sodium flame masks at first by its intensity the characteristic calcium colour, the red of which will appear to be slightly mingled with the characteristic yellow of the sodium. By examining the flame through a piece of dark blue glass the crimson colour of potassium may also be detected by a *skilled observer*, but the quantity present is so small that rapid and delicate observation is essential.

The presence of sulphur in eggs is common knowledge, owing to the staining of silver spoons and to the highly objectionable odour of rotten eggs, due to the formation of hydrogen sulphide. Sulphur forms a grayish black compound with silver (a sulphide of silver), insoluble in water or in any alkaline liquid of a strength which would not also dissolve the silver exposed to its action, hence the tarnishing of silver spoons or forks when used for eating eggs. Such articles should be rubbed before washing with common salt; a silver chloride is then formed, soluble in ammonia, which should be added to the water in which the spoons are subsequently cleansed.

III.—To show the Presence of Proximate Food Principles in Cheese (*Fig.* 65, *page* 327).

MATERIALS: *Cheshire, American or Dutch cheese; soda lime;* 1% *solution of osmic acid; alcohol; benzine; lime-water; iodine; filter paper; neutral litmus paper; water. Biuret test, page* 169.

APPARATUS: *Test tubes; beaker; c.c. measure; watch glass; glass rod; funnel; small porcelain dish; retort stand; sand-bath; air-oven; Bunsen burner.*

(*A*) *Nitrogenous Substances.* (*Proteids.*)

(1) Grate about 5 grams of fresh Cheshire, American, or Dutch cheese into a small porcelain dish and cover with 30 c.c. lime-water. Mix thoroughly with a glass rod, and filter. Test for proteid by the Biuret reaction (*page* 169).

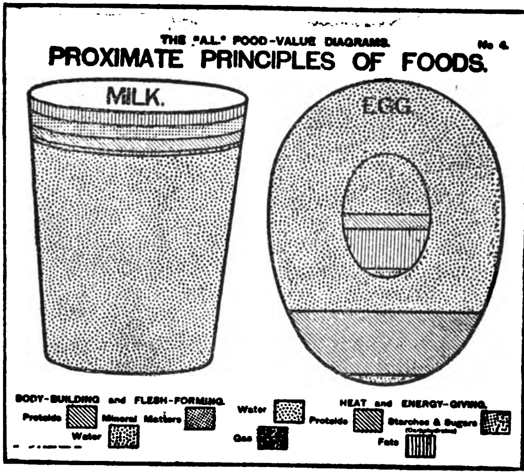

FIG. 63. FIG. 64.

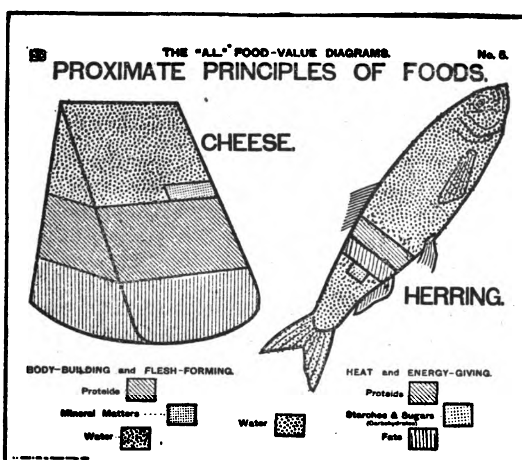

FIG. 65. FIG. 66.

(2) Dry a piece of cheese in the air-oven for about 24 hours at a moderate temperature.

Break it up into very small pieces and mix it with powdered soda-lime, moisten the mixture sufficiently to roll into small balls about the size of a large pill. Place three or four of these balls in a dry test tube and proceed to test for the presence of nitrogen, as directed on *pp.* 171-2.

(3) Mix about 14 grams ($\frac{1}{2}$ oz.) of a well-matured cheese in warm water; filter, and reserve the residue for use in (*C*).

Divide the filtrate into two parts; test one part with neutral litmus paper; and the second for the presence of proteid, by the Biuret reaction (*page* 169).

NOTE.—The reaction with litmus will be acid, and the typical violet colouration will indicate the presence of proteids in the filtrate.

(*B*) *Carbohydrates.*

Grate into a small porcelain basin about 5 grams of cheese similar to that used in (*A*); cover with 30 c.c. distilled water and mix thoroughly with a glass rod.

Divide into three test tubes (*a*), (*b*) and (*c*), reserving (*c*) for the next experiment.

Test (*a*) for starch and (*b*) for sugar, as directed *pp.* 173-4.

NOTE.—The proportion of carbohydrates in cheese varies widely; as much as 8·9% has been found in skim milk cheeses, such as Dutch cheese, but a trace only may be present in full cream cheeses, such as Stilton: it is possible therefore that no reaction may be obtained to either test.

(2) Take the residue set aside in (*A*) (3), wash it several times in warm alcohol, the same portion of which can be used for each washing, filter the mixture between each extraction. Repeat the process with benzine. Evaporate some of the clear liquid in a watch glass over a warm water or sand bath, and observe the greasy residue which remains in the glass.

IV.—To show the Presence of Proximate Food Principles in Fish (*Fig.* 66, *page* 327).

MATERIALS: *Fresh herring or sprats; cod or fresh haddock;* 2 *scallops or oysters; hydrochloric acid; nitric acid; acetic acid;* 1% *osmic acid; sodium carbonate; ammonium molybdate; iodine;* 95% *alcohol; Fehling's solution; filter paper; water.*

APPARATUS: *Beakers; test tubes; large pipette; funnel; pestle and mortar; saucer or small plate; platinum boat or porcelain crucible; air-oven; retort stand; Bunsen burner.*

(*A*) *Nitrogenous Substances.* (*Proteids.*)

(1) Take portions of the flesh of a raw fresh herring or of two or three sprats. Grind up with clean dry sand in a mortar, transfer to a beaker, add just enough water to cover the mass, and boil. Set aside a small quantity for use in (*C*) and add a few drops of acetic acid to the larger amount left in the beaker, this will assist in the precipitation of the proteid present in the fish. Filter, and divide the filtrate into three test tubes (*a*), (*b*), (*c*). Test the contents of each test tube for evidence of proteid, as directed *pages* 168-9.

(2) Repeat (1), but substitute raw cod or fresh haddock for the herring or sprats employed in that experiment.

NOTE.—With herring or sprats the most characteristic reaction will be obtained by the xanthoproteic test; with Millon's reagent the precipitate will only become pinkish on cooling instead of brick-red, while but a faint violet colouration will be secured with the Biuret test. Cod or fresh haddock gives excellent results with all three tests.

(*B*) *Carbohydrates.*

Grind up two scallops or oysters in a mortar with sand, transfer to a beaker, add just enough water to cover the mass, and boil.

By this treatment the *glycogen* is dissolved and the proteid present is partially precipitated. Complete the precipitation by the addition of a few drops of acetic acid. Filter, and add 95% alcohol to the filtrate until the glycogen falls as a white

precipitate, which, though soluble in weak alcohol, becomes insoluble in an alcoholic solution of over 60%. Allow the precipitate to settle, draw off the clear liquid by means of a large pipette and then filter the residue.

Scrape the solid substance (glycogen) off the surface of the filter paper and divide into two portions (*a*) and (*b*). Test (*a*) for starch with iodine, a reddish, port-wine colour will result.

Boil (*b*) for 15 or 20 minutes with the addition of dilute hydrochloric acid. Neutralize the solution with sodium carbonate and test with Fehling's solution. Observe the change from *glycogen* into *glucose* brought about by heat and acid.

NOTE.—Carbohydrates in any form are absent from every kind of fish except oysters and scallops, in which they are present as glycogen, or animal starch.

(*C*) *Fats.*

Half-fill two test tubes with some of the prepared fish reserved from (*A*).

Add a few drops of osmic acid (1%) to each test tube and compare the very slight reaction, if any, obtained from the flesh of cod or haddock, with the satisfactory evidence afforded of the fatty character of sprats or herring.

NOTE.—An even more marked contrast will be obtained if the flesh of salt mackerel or herring be substituted for the fresh fish in this experiment, for the percentage of fat present reaches 17% in the case of the former and 36% in the latter; whereas in cod and haddock, whether fresh or dried, traces only are to be detected, ·3 and ·4 per cent. respectively.

A light brown colour, *very gradually* becoming darker, will be obtained with cod; with herring, whether fresh or salt, there is *immediate* reaction to the osmic acid solution.

(*D*) *Salts.*

Take about 15 grams (½ oz.) of the flesh of either fish used in (*A*), (*B*), (*C*). Place in a saucer or small plate in the air-oven until it is completely dried. Break off a very small piece of the dried fish and burn off all combustible matter, preferably in a platinum boat, otherwise in a porcelain

crucible. Add sufficient dilute nitric acid to the ash to dissolve it, filter the solution, and test for phosphates with ammonium molybdate. A thick, yellow precipitate will be thrown down immediately, which darkens a little on warming.

NOTE.—As fish is rich in phosphates, three or four drops of the fish ash solution is sufficient for the test, as the ammonium molybdate must be largely in excess to make the experiment a success.

V.—To show the Presence of Proximate Food Principles in Flour.

MATERIALS: *Flour; nitric acid; 1% osmic acid; ammonium molybdate solution; Fehling's solution; Millon's reagent; iodine; benzine; filter paper.*

APPARATUS: *Beakers; test tubes; c.c. measure; funnel; thermometer; porcelain dishes; evaporating dish; spatula; balance; sand-bath; air-oven; retort stand; Bunsen burner.*

(*A*) *Nitrogenous Substances.* (*Proteids.*)

(1) Place 28 grams (1 oz.) of finely ground flour in a porcelain dish; mix well with a nearly equal quantity of water at a temperature from 13° to 15° C. (55° to 59° F.). Work it up into a ball with a spatula and set it aside for an hour.

(2) Hold the ball in the hand and knead under a stream of fresh water until the starch and other matters that can be washed out are removed, that is, until no milkiness is produced. Be careful to collect these washings for use in (*B*) and (*C*). Place the residue in cold water, and again leave for one hour. On removal, press as dry as possible; the product is *gluten*.

(3) Heat a little of the gluten and observe that it solidifies first and afterwards blackens, giving off an odour of burnt feathers.

NOTE.—The blackening is due to carbon. The smell is a common characteristic of many substances which contain nitrogen.

(4) Place a little of the gluten in a test tube and test for proteids with Millon's reagent (*page* 168).

(5) Filter some of the milky fluid, and boil the filtrate. A faint precipitate is produced, showing that coagulation has taken place, consequently that albuminous matter is present in flour.

(*B*) *Carbohydrates.*

(1) Take a little of the milky fluid obtained from the kneading of the flour in (*A*) (2). Boil it in a test tube and observe that it becomes clear during the process; compare the appearance of the solution with that obtained in the experiment on *page* 293.

Test the solution for starch, by adding a drop of iodine to the contents of the test tube.

(2) Test a portion of the *unfiltered* milky fluid for grape sugar by Fehling's solution.

Which form of carbohydrate is present in flour?

(*C*) *Fats.*

Mix a little flour thoroughly with benzine in a test tube, and shake well for some minutes.

Filter off the solid and divide the filtrate into two portions (*a*) and (*b*). Test (*a*) for evidence of the presence of fat, by carefully evaporating the liquid in a clean, dry evaporating dish over a warm-water or sand-bath. Does the residue appear greasy to the eye or to the touch? To (*b*) add a few drops of 1% osmic acid solution.

The amount of fat present in refined wheat flour is so small that very little, if any evidence, will be obtained of its presence.

(*D*) *Salts.*

Place 5 grams of dry flour in a small porcelain basin and bake it thoroughly in the air-oven. Observe the changes of colour which take place. Then set a light to the dried flour and burn it to ashes. The grey ash is chiefly

phosphate of potassium, which can be proved as follows:—Cool the ashes and slide them into a test tube; drop in very carefully a few drops of concentrated nitric acid, add water and boil; this treatment dissolves any phosphates present. Filter, and allow 7 or 8 drops of the filtrate to drop into 10 c.c. ammonium molybdate solution. Heat gently (*see page* 178). The degree of reaction will depend largely upon the quality of the flour and the character of the soil in which the wheat grew.

(*E*) *Water.*

Weigh a small basin and half fill it with flour. Weigh it again and record the weight; the difference will give the weight of the flour.

Place the basin in a hot air-oven for two hours. Then remove it and weigh it again. Replace the basin in the oven, dry the contents for two hours more, weigh again and repeat the process until the loss of weight due to evaporation of the water remains constant after two weighings (*page* 182).

VI.—To show the Presence of Proximate Principles in Bread (*Fig.* 68, *page* 335).

MATERIALS: *Stale white bread; nitric acid; 1% copper sulphate solution; Fehling's solution; Millon's reagent; potash solution; iodine solution; alcohol; ammonia; filter paper.*

APPARATUS: *Beakers; test tubes; c.c. measure; funnel; glass rods; retort-stand; Bunsen burner.*

The presence of proteids and starch in bread can be simply demonstrated by the following method. (*Fig.* 68, *page* 335.) Cut a thick level slice of stale, white bread.

(*A*) Dip a glass rod in strong nitric acid (the xanthoproteic test) and make a streak on the flat upper surface of the bread, immediately covering the same portion with ammonia, also applied with a glass rod.

Dip a clean glass rod in Millon's reagent and make a similar streak side by side with the first.

Prepare the chemicals for the Biuret test by shaking a few drops of 1% copper sulphate solution in a test tube, empty these away (thus leaving a mere trace of the copper sulphate in the tube) and add 5 c.c. distilled water. Dip a glass rod into the tube and make a third streak beside the other two, covering it immediately with a streak made with a glass rod dipped in strong potash solution.

NOTE.—The colour changes associated with these three tests for the presence of proteids can thus be seen side by side; the most convincing results follow the use of Millon's reagent, which turns brick-red in a few minutes at room temperature.

(*B*) Dip a glass rod in iodine solution and draw a fourth streak on the bread; very visible evidence of the presence of starch is instantaneously afforded.

Take a piece of crust cut from the same loaf as the bread used in (*A*). Soak it well in a measured quantity of cold distilled water, then add to this rather more alcohol than water to precipitate dextrine if present; filter, and divide the filtrate into two portions (*a*) and (*b*).

Test (*a*) with iodine; is the reaction that of starch (blue) or dextrine (port-wine colour)?

Take 1 c.c. of (*b*) and boil with 15 c.c. of Fehling's solution. Is dextrose present in sufficient quantity to give the characteristic reaction?

NOTE.—The effects of dry heat on starch at a high temperature are shown by the fact that the dextrine and dextrose are found in the *crust* of the bread, which will have been exposed to a temperature of 210° to 280° C. (410° to 536° F.), whereas in the interior of the loaf the normal character of the starch remains unchanged.

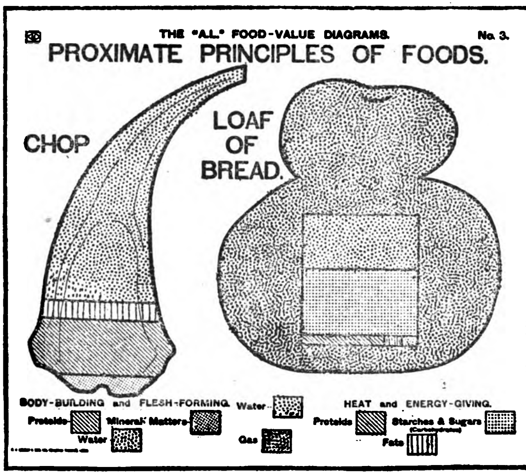

Fig. 67. Fig. 68.

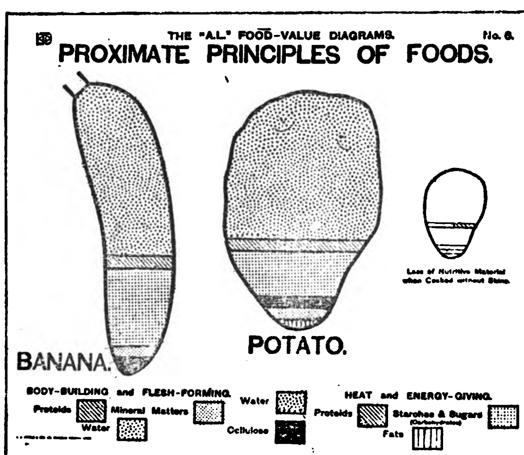

Fig. 69. Fig. 70.*

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* *Figs.* 61 to 70 are reductions of the "A.L." **Food-Values Diagrams** by Miss Ravenhill and Miss Morris; a set of six large Charts, 42-in. × 33-in., boldly drawn and coloured for class use. Mounted on calico, net 3/6 each, or the set, net 18/-; the six sheets on manilla under top-lath, net 12/-. *E. J. Arnold & Son, Ltd., Leeds.*

VII.—To show the Presence of Proximate Food Principles in Cereals.

MATERIALS: *Cereals (semolina, tapioca, rice, etc.); nitric acid; ammonium molybdate; iodine; alcohol; Fehling's solution; filter paper.*

APPARATUS: *Test tubes; funnel; glass rod; pestle and mortar; retort stand; Bunsen burner.*

GENERAL DIRECTIONS.

Powder each specimen as finely as possible in a mortar.

Divide into three portions (*a*), (*b*), (*c*).

Test (*a*) with iodine for the presence of starch. Soak the contents of (*b*) in cold water, add alcohol in excess; filter, and divide the filtrate into two portions. Test one with iodine for *dextrine*, test 1 c.c. of the second with Fehling's solution (15 c.c.) for *dextrose*.

Take the insoluble residue left in the filter and test for *proteids* (*pp.* 168-9). Note with which test the best reaction is secured.

Reduce (*c*) to ashes by placing it in a porcelain dish; weigh and proceed as directed in "GENERAL CONSTITUENTS OF THE BODY," IV. (*B*), (*page* 176). When the weight remains constant, all the volatile matter will have passed off and the residue will be ash.

Cool, make an extract with water, filter, and test portions of the filtrate for chlorides (*p.* 177), and sulphates (*p.* 178). Add a few drops of concentrated nitric acid to the residue in the filter. Boil, USING GREAT CAUTION; dilute with water, filter, and test the clear filtrate with ammonium molybdate (*p.* 178) for the presence of *phosphates*.

NOTE.—Samples of semolina, tapioca, rice, pearl barley, cornflour, oatmeal or Quaker oats, arrowroot and vermicelli can all be tested by this method for the presence of the various proximate principles.

The proportions in which proteids and starch are present in these cereals vary very considerably, so that students should be encouraged to tabulate their own estimates of the general relative proportions of these proximate principles. These estimates should be based upon careful observations of the colour reactions given by the selected samples, each sample being prepared by the same process and subjected to similar tests. They should subsequently compare their conclusions with published tables showing the accepted analysis (*p.* 282).

VIII.—To show the Presence of Proximate Food Principles in Vegetables and Fruits (*Figs.* 69, 70, *page* 335).

MATERIALS: *Potatoes; parsnips; lentils; bananas; apples; orange; walnuts or almonds; hydrochloric acid; nitric acid;* 1% *osmic acid solution; ammonium molybdate; ammonium oxalate; Fehling's solution; iodine; alcohol; copper oxide; soda-lime; ammonia; butter muslin.*

APPARATUS: *Beakers; test tubes; glass gas-jar or glass fruit-bottle; pipette; c.c. measure; dark blue glass; pestle and mortar; basins and dishes; grater; platinum-foil boat or crucible; silver knife; steel knife; platinum wire; balance; water-bath; air-oven; Bunsen burner.*

(*A*) *Potatoes* (*Fig.* 70).

(1) *Carbohydrates.*

(*a*) Carefully clean a small, sound potato and grate it over a shallow dish. Collect the gratings in a small bag made of butter muslin and wash and squeeze this well in not less than 1 litre ($1\frac{3}{4}$ pint) of water, which should be allowed in the first place to stream down on to the grated potato; finally turn out the contents of the muslin bag and stir the whole well into the water collected during the washing process.

(*b*) Prepare a filter with muslin as directed on *page* 307, and pour the milky fluid from (*a*) through this filter into a tall glass gas-jar or glass fruit-bottle. Leave the liquid to settle for 24 hours.

(*c*) Scrape off some of the residue left on the surface of the filter, put it in a test tube, add a little water and test it for starch with a drop of iodine. Dry the residue at a temperature not exceeding 70° C. (158° F.) over a water-bath.

(*d*) (i.) Grate about 10 grams of the raw potato into a porcelain dish, moisten with dilute nitric acid, dry the paste by evaporation over a water-bath, and finally heat in the air-oven to a temperature slightly above 100° C. (212° F.). Cool the powder, moisten it with water, add alcohol to precipitate the dextrine, filter, wash again with alcohol, and test for *dextrine* with iodine.

(ii.) Repeat (i.) but use 10 grams of the dry starch prepared in (*c*). Are the results alike in the two cases?

(*e*) Use about three grams of the dried starch prepared in (*c*); mix with 200 c.c. of water and add 5 c.c. hydrochloric acid. Boil for a quarter of an hour. Cool, neutralize cautiously with sodium carbonate, and test a small quantity of the liquid for the presence of *dextrose* with Fehling's solution.

(*f*) Pour off, or withdraw by a pipette, the supernatant fluid from the jar in (*b*), and test the sediment for *starch* with iodine.

NOTE.—The results of these tests, though only of a qualitative character, will demonstrate the high proportion of starch (18·5%) present in potato.

(2) *Nitrogenous Substances.*

Transfer portions of the liquid drawn off from the jar into three test tubes (*a*), (*b*) and (*c*). Test these respectively for the presence of proteids.

NOTE.—The proportion is so very small (2·2%) that better results will be obtained if the filtrate be considerably concentrated by *slow* evaporation over a sand or water-bath before the tests be applied. Fat is practically absent from potatoes, as, indeed, it is from all vegetables and fruits except nuts and olives.

(3) *Water.*

Weigh a small potato and cut it into slices, place these in a dish of known weight, but take the precaution of noting the combined weight of the dish and its contents before introducing it into the air-oven. Proceed as directed, *p.* 182.

NOTE.—The percentage of water in potato is so high (at least 78 %) that the process of desiccation will necessarily be prolonged.

(4) *Salts.*

Cut a thin slice of raw potato, free it entirely from dirt and place it on a clean saucer in the air-oven until charred. Fix a portion of this charred substance in the platinum coil, insert it in the outer flame of the Bunsen burner, the flame will quickly assume the yellow tint characteristic of *sodium.* Have a piece of dark-blue glass at hand, and look through this also at the charred fragment of potato as it is held in the flame; a vivid crimson tint will be visible, though, as the vegetable is so rich in *potassium*, a lilac flame may even be distinguished by the eye without the glass.

(5) To demonstrate that the nitrogenous principles and salts are present in the juice of the potato, subject a potato to sufficient pressure and squeezing to separate the juice from the solid portion.

Test the solid residue for *starch* with iodine, but divide the juice into two portions (*a*) and (*b*). Test (*a*) for proteid by the xanthoproteic test (*page* 168); test (*b*) for *potassium salts* by adding just enough of the solid residue to the juice to give it a sufficient consistency, so that some drops will adhere to the platinum wire when dipped in the fluid. Then proceed as directed above (4).

NOTE.—Potatoes are so deficient in proteids that alone they do not constitute a complete diet, but they are very useful when eaten with highly nitrogenus foods, such as meat, fish, or eggs, and are of great value, when properly cooked, for their antiscorbutic properties.

(*B*) *Parsnips.*

Prepare a fresh pulled parsnip as directed in (*A*) (1) (*a*), and carry out, with the emulsion thus prepared, the series of tests given for the presence of the proximate principles in potatoes.

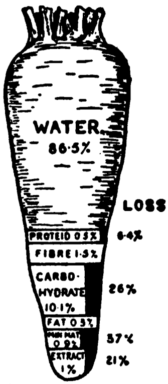

FIG. 71.—CARROT.*

NOTE.—The parsnip is poorer in carbohydrates (13·5%) and proteids (1·6%) than is the potato, but it is valuable for the variety it affords in diet, and for its flavour as well as for its antiscorbutic properties. It is typical of the whole group of root vegetables — carrots, beets, turnips, and radishes.

(*C*) *Lentils.*

Crush some dried lentils to a fine powder in a mortar and proceed as directed under (*A*); that is, first prepare an emulsion with the lentil powder and then test the filtrate and residue for the various proximate principles.

NOTE.—The legume group includes peas, beans and lentils; all these are rich in proteids (about 22%), in a form which resembles the animal proteid, casein, present in milk. Dr. Winter Blythe gives the following directions for the isolation of this nitrogenous principle in legumes. "To prepare legumin powder dry some peas and treat the flour with successive quantities of cold water made slightly alkaline with soda. Precipitate the legumin present in this solution with acetic acid. To purify it, dissolve the precipitate in a weak solution of potassium hydroxide and reprecipitate with acetic acid. The pure alkaline solution should give a violet colour with copper sulphate solution."—*Foods, Their Composition and Analysis.*

* Reproduced from "Food and the Principles of Dietetics," R. Hutchison, M.D., by kind permission of Mr. Edward Arnold.

Legumes offer a fair substitute for the more expensive forms of nitrogenous animal foods but they are much more difficult of digestion than cereals and are less well absorbed than animal foods, so that even when ground to a state of very fine subdivision and exposed to prolonged cooking Rubner has shown that a fifth to a third of the proteids present in legumes are neither digested nor absorbed, consequently a large proportion is excreted unchanged. Even Galen (born about 130 A.D.), pointed out that the pulses are harder to digest than other foods and "give bad dreams."

Dr. Hutchison considers these qualities to be "no doubt partly owing to their bulkiness when cooked." Thus 150 grams ($5\frac{1}{3}$ ozs.) of lentils in the form of a mash (about a soup-plateful), remained in the stomach four hours, and 200 grams ($7\frac{1}{4}$ ozs.) of peas in a similar form for four hours and a quarter. He also points out that the prolonged cooking essential to rupture the cellulose walls, in which the nutrient principles are enclosed, coagulates and hardens the proteid matters present, while shrinkage of their contents may actually result in the cellulose envelopes remaining unruptured and may thus account for the non-absorption of these substances by the intestines. This opens up the whole question of vegetarianism, an impartial discussion of which is to be found in Chapter X. of Dr. Hutchison's book on "*Food and the Principles of Dietetics.*"

The consumer of a mixed diet solves these problems of relative absorbability and bulk in animal and vegetable foods by combining a moderate amount of the more expensive foodstuffs, obtained from animal sources, with a considerable proportion of cheaper vegetable material. Bread and bacon or eggs, for instance, bacon and beans, meat or fish and potatoes, Irish stew or ham on toast are all familiar examples of such combinations of animal with vegetable foods.

Among the cheapest kinds of foods the following combinations have been recommended by Dr. Niven, Medical Officer of Health for Manchester. Bread and milk or skim milk, bread and cheese, bread and herrings, bread and margarine or oil, oatcake and margarine, oatcake and cheese, oatmeal as porridge and sugar, peas and margarine or oil.

The more bulky, less digestible vegetable forms of nitrogen in oats, peas, beans and lentils suit equally the digestive capacities and the slender purses of the farmer and his men, whose blood is well oxygenated in the pure air, and whose

muscular exertions demand a high percentage of carbohydrates while directly promoting the absorption of the vegetable proteids with which they are combined. Even though legumes may be consumed by him in the strictest moderation, the sedentary worker finds that he derives greater benefit from the more easily digested and at the same time more concentrated forms of animal food, which his usually higher scale of remuneration enables him to include in his daily diet.

To the debilitated and starving, preparations of these leguminous vegetables often offer many digestive difficulties, and cannot be considered cheap unless subjected to special and relatively expensive methods of preparation; to the strong, active, well-nourished individual they offer an inexpensive and agreeable variety of food.

(*D*) *Bananas* (*Fig.* 69, *page* 335).

Make an emulsion of banana, preferably before the fruit is over ripe, as directed in (*A*) (1), and carry out the series of tests given in that section for the purpose of detecting the presence in this fruit of the proximate principles of food, using the preparation of banana in place of potato.

NOTE.—The banana is typical of a food fruit, as it contains about 22% of carbohydrates and 1·5% proteid. At the same time it illustrates admirably the difficulty of employing vegetable nutrients only for dietetic purposes. The calculation has been made that if it were desired to sustain life on no other food than this fruit the daily demand for proteid could only be met by the consumption of at least 150 bananas, though half that number would suffice to yield the daily supply of energy.

The fruit should be cooked, if eaten in any quantity by children and invalids, in order to liberate the carbohydrates, which are present in such a large proportion, from their cellulose envelopes.

Bananas constitute a nutritious and wholesome addition to a mixed diet, and from their cheap and prolific cultivation contribute usefully to the food-stuffs of the world.

Dates and figs are the most highly nutritious of all fruits. "Weight for weight dried figs are more nourishing than bread," 1 pint of milk and 6 ozs. of dried figs or half a pint of milk and half a pound of dates are stated to make respectively an ample and satisfying meal.

(*E*) *Apples.*

(1) *Water.*

Take an apple of moderate size; weigh it, cut it into slices with a silver knife, place these in a clean porcelain dish and weigh again a second time. Now put the dish and its contents in the air-oven until all moisture has disappeared from the top and sides of the oven, but regulate the temperature so that it does not much exceed 100° C. (212° F.). Weigh again, and continue the desiccating process at intervals of at least two hours until the results of two weighings are the same (*page* 182).

The difference between the first and last weighing will show the percentage of water present in the fruit. This averages 82·5% in fresh apples, but can be reduced to 36·2% by desiccation (*Fig.* 72).

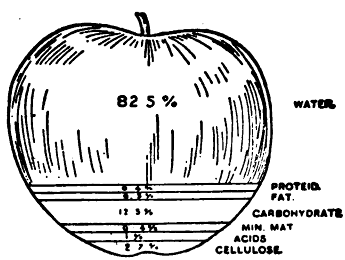

FIG. 72.*

(2) *Nitrogenous Substances.*

Grind and bruise a portion of the dried apple in a mortar and mix it well with about an equal volume of soda-lime. Proceed as directed on *page* 172.

The result will show the presence of nitrogenous compounds in apples, where proteids are represented to the extent of 0·4%.

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(3) *Carbohydrates.*

(*a*) Crush a fresh apple in a mortar, collect the crushed pulp in some butter muslin and squeeze the juice into two test tubes (i.) and (ii.). Test (i.) with Fehling's solution for "*invert*" *sugar*, which, like dextrose, has a reducing action with Fehling's solution (*page* 174).

(*b*) Filter the contents of (ii.) and add an equal volume of alcohol to the filtrate. A gelatinous mass will be precipitated which consists largely of *pectin*, a form of carbohydrate characteristic of ripe fruits. Compare the consistency and flavour of this jelly with the juice which exudes from apples while baking.

NOTE.—The agreeable flavours associated with most fruits depends upon the relative proportions of pectin, sugar, gum, acids and other constituents. Fruits contain so little proteid matter that their chief food-value exists in the sugar, salts and vegetable acids which they contain. The carbohydrates are present chiefly in the form of *levulose*, or invert sugar and pectin, though cane sugar is also found in apricots, apples and pine-apples. The pectous bodies are not yet fully understood, though their relationship to carbohydrates is established. It has been stated that *pectin*, a vegetable jelly, is the ripened derivative of *pectose*, the change being brought about by the action of acids. This pectin is responsible for the fact that juice gelatinizes when cooled after boiling. If a handful of damsons or cranberries, for instance, be stewed with a very little water, and the juice be first filtered and then allowed to cool it will gelatinize freely, in consequence of the pectin present in the fruit, the proportion being larger before the fruit is fully ripe.

(*F*) *Oranges.*

(1) *Water.*

Take a large orange, peel, divide the pulp in half and cut up one half with a silver knife in a clean, porcelain dish. Weigh, and proceed to extract the water by slow evaporation as directed in *page* 182.

Water is present to the extent of 86%.

(2) *Nitrogenous Substances.*

Crush the dried pulp in a mortar; add an equal volume of soda-lime, and proceed to demonstrate the presence of proteid as directed *page* 165.

About 0·8% is present in the fruit.

(3) *Carbohydrates.*

Take the pulp of the second half of the orange used in (1) and collect the juice as directed in *apples* (3) (*a*). Test a few drops with Fehling's solution for the presence of sugar (*page* 174).

(4) *Salts.*

(*a*) *Phosphates.*

Place a small quantity of the desiccated pulp prepared in (1) in a clean porcelain dish and char it at a high temperature into a black, calcined mass. Crush this to a powder, and burn off as much as possible of the remaining organic matter, preferably in a platinum-foil boat, but otherwise in a crucible.

Dissolve the residue with nitric acid, filter, and test for *phosphates* with ammonium molybdate, as directed *page* 178.

(*b*) *Calcium.*

Treat a second portion of the dried pulp as directed in (*a*) but dissolve the ash in dilute hydrochloric acid. Filter, and neutralize the filtrate with dilute ammonia; the liquid may be made just slightly alkaline. Use the greatest care in the process. Add a few drops of a solution of ammonium oxalate until a copious precipitate forms, this is *calcium oxalate*, the product of the chemical reaction which takes place when ammonium oxalate is added to a neutral or alkaline solution of any calcium salt.

(c) *Potassium.*

Divide an orange into four quarters, take one of these and squeeze the juice into a small porcelain basin. Add to the juice the flesh of the part of the orange from which it has just been squeezed, and expose the contents to a temperature of 110° C. (230° F.) in the air-oven, until slightly charred.

Then place a piece of the charred substance in the coil of platinum wire, and hold the wire in the outer flame of a Bunsen burner. Hold a piece of dark-blue glass in the disengaged hand, and look through this at the flame the instant the orange powder is brought in contact with it. The reddish-violet flash will be large and brilliant, but brief in its continuance.

NOTE.—It is to their mineral constituents as well as to their carbohydrates that fruits so largely owe their value. Potash salts preponderate, united with tartaric, citric, malic and other vegetable acids. The pleasant and refreshing flavour of these acids is but one of their good qualities, for when oxidized in the body they become converted into the corresponding carbonates, assisting to maintain the alkalinity of the blood and to reduce the acidity of the urine. These vegetable acids diminish in quantity as fruit ripens, while the amount of sugar increases, hence the difference in flavour between ripe and unripe fruit. Fruits are chiefly eaten on account of their agreeable flavour, but they are useful also as a stimulus to peristaltic activity, a gently irritating effect being exercised on the intestinal walls by the acids and cellulose, of which from 4 to 5 % of the latter is usually present.

Colic and diarrhœa represent the exaggeration of this beneficial action, and occur usually in consequence of the injudicious consumption of *unripe* fruit, where the cellulose and the acids are present in larger quantity and in more irritating forms.

(*G*) *Walnuts or Almonds.*

(1) *Water.*

Remove a walnut from its shell, weigh, break in pieces, place in a small porcelain dish and proceed to dehydrate as directed *page* 182.

Notice the very small proportion of *moisture* present, not more than 4%. (*Fig.* 73).

(2) *Nitrogenous Substances.*

Crush half the dried nut in a mortar; mix with an equal volume of soda-lime and proceed to test for *nitrogenous substances*, as directed *page* 172.

(3) *Carbon as Carbohydrate and Fat.*

(*a*) Crush the remainder of the dried nut in a mortar to a very fine powder, taking the precaution to expose it first in the air-oven to a temperature sufficiently high to blacken and char it.

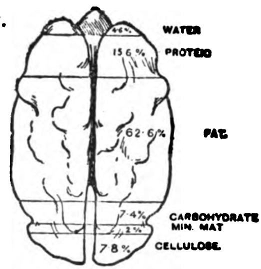

Fig. 73.*

Mix this fine powder with 20 times its volume of finely divided copper oxide, and proceed to test for *carbon* as directed *page* 184.

(*b*) Crush a fresh walnut in a mortar, place the pulp in a small porcelain basin and test for *fat* with 1% osmic acid solution.

Note.—Nuts are very rich in proteids and fats, but contain no starch. They are a very concentrated but not easily digested form of nourishment. The percentage of proteids in walnuts, for instance, is 15·6% and in almonds it is 11·5%. Of fat, the percentage is 62·6% in the former and 30·2 % in the latter nut. No other vegetable substance is so rich in fats, hence it is to nuts that vegetarians look for their chief source of carbon, various nut preparations being used as substitutes for butter. These are actually more economical and equal in nutritive value to animal fats, while to a large extent the digestive difficulty has been overcome by skilful preparation.

Thorough mastication suffices, with healthy people, to break down the dense framework or cellulose in which the nutrients of nuts are enclosed, so rendering the fruit digestible and a valuable article of diet when consumed with discretion at meals.

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(4) *Salts.*

Nuts are very rich in phosphates; the test on *page* 178 can be successfully carried out with almost any kind of nut if the kernels be cut cleanly into very thin slices, the organic matter burnt off, and the "nut ash" treated with dilute nitric acid, filtered, and tested with ammonium molybdate.

XVI.—THE EFFECTS OF COOKING UPON FOOD.

Illustrations of the applications of heat for cooking purposes. The effects of cooking upon meat, eggs, farinaceous foods, vegetables, water, fat, food combinations.

I.—Illustrations of the Application of Heat for Cooking Purposes.

MATERIALS: *Raw meat; suet; carrot; cornflour; flour; butter; dripping; water; cloth.*

APPARATUS: *Beakers; small china dish; enamelled cup; spoon; small metal plates or sheets; thermometer; knife; air-oven; balance; Bunsen burner.*

(*A*) *The Action of Dry Heat.*

(1) *On Meat.*

Take 250 grams (½ lb.) of raw meat, wipe well with a damp cloth and divide into two portions (*a*) and (*b*), place each on a small plate or sheet of greased metal and dredge with flour.

Raise the temperature of the air-oven to 115° C. (239° F.) and place (*a*) on the shelf within. Maintain the temperature until the meat is brown (about five minutes) then lower the temperature to 105° C. (221° F.) by diminishing the source of heat, and baste the meat, that is, ladle over it with a spoon a small quantity of melted fat (butter will serve the purpose in this experiment).

The fat and flour, aided by the heat, form a crust which imprisons the juices of the meat and prevents the lean from charring. Remove (*a*) in five minutes. Observe the taste, odour and appearance.

Repeat the process with (*b*) but maintain the high temperature throughout the cooking process, and do not baste. Compare the results of the two methods of cooking upon the appearance, consistency and flavour of the two specimens.

(2) *On Flour.*

Take about 28 grams (1 oz.) of flour, divide into two portions (*a*) and (*b*).

Spread (*a*) over the surface of a flat sheet of metal or small china dish and expose for 20 minutes to a temperature of about 105° C. (221° F.) in the air-oven.

Prepare two beakers and half fill each with warm water. Stir (*a*) into the contents of one and (*b*) into the contents of the other beaker.

Observe the marked difference between the two specimens of flour in respect of flavour and thickening qualities.

(3) *On Fat.*

Place some dripping or suet in a small beaker or enamelled cup and heat over a Bunsen flame. Notice the acrid, unpleasant odour as the fat reaches a high temperature. Pour the melted fat into a clean vessel and set aside to cool. What change is to be observed in its appearance?

NOTE.—Hot fat often proves irritating to delicate digestions in consequence of the liberation of free fatty acid which follows upon its partial decomposition by heat. When fat which has been heated is allowed to cool, it becomes more granular and brittle, probably owing to the evaporation of the contained water. As a result, it usually proves more easy of digestion.

(*B*) *The Conjoint Action of Heat and Moisture* (boiling, steaming, stewing, etc.).

(1) *On Meat.*

Take two small pieces of raw meat of about equal size, (*a*) and (*b*), and put them into two beakers.

Immerse (*a*) in cold water, cover the vessel and set aside for ten minutes, then raise the temperature of the contents to boiling point and maintain at this temperature for ten minutes.

Immerse (*b*) in boiling water, place the beaker over a Bunsen flame and maintain at this temperature (100° C.) for two minutes, then simmer gently for a further period of five or more minutes at 74° C. (165° F.) according to the size of the piece of meat.

Examine both (*a*) and (*b*) in respect of appearance, flavour and consistency when cut or eaten. The water will have extracted most of the soluble nutritive principles from (*a*) which will be tasteless and tough; the coagulation of the surface albumin in (*b*) by the boiling water will have left the meat tender, juicy and well-flavoured. The "scum" on the surface of the beaker containing (*a*) is evidence not only of the loss of albumin from the meat but of valuable flavouring and other constituents known as "extractives," which are present in animal foods. They are not only appetizing but apparently contribute to the nutritive value of meat, fish and other such foods.

(2) *On Vegetables.*

Cut a carrot into pieces, place a few of these in a beaker, cover with boiling water, and maintain at this temperature until the pieces of carrot are softened.

Compare these as to flavour and tenderness with the uncooked portions.

(3) *On Starch Foods.*

(*a*) Mix a few grains of cornflour with cold water, observe the sediment which forms.

(*b*) Mix an equal quantity of cornflour with hot water, some of the starch granules will burst, though others remain unaffected.

(*c*) Boil for a few minutes a similar quantity of cornflour which has been previously mixed with water in the same proportion as in (*a*) and (*b*).

The appearance, consistency and flavour will all undergo marked changes as a result of this cooking process.

NOTE.—Cooking consists primarily in the application of heat to food-stuffs, or in their manipulation in such fashion as to promote their digestibility. For instance, meat is minced or pounded to forestall mastication; cheese, almonds, peas, coarse meal, etc., are grated or ground to expose larger surfaces to the digestive juices; glairy fluids are whisked or beaten to render them porous and to separate into particles otherwise dense or tenacious masses. Fat and oil are emulsified in sauces, and concentrated liquids are diluted, while cleanliness is promoted by exposure to heat, both moist and dry. As all food must also be raised to the temperature of the body before the process of digestion can begin, energy and heat are both economized in the body when food is eaten warm. It thus appears that cooking is designed in some cases to increase the digestibility of food stuffs, in others to ensure cleanliness, in nearly all to improve their appearance and flavour, and generally to enable various substances of different kinds to be combined in order (1) to increase their nutritive value, (2) to neutralize the effect of the undue proportion of any food principle, or (3) to provide desirable variety in the diet.

Thus food when well cooked is usually more appetizing, more wholesome, and capable of being more varied in form and flavour than when raw. Indigestible portions, or those which have been damaged or which give evidence of decay or putrefaction can be removed, while the natural flavours can be emphasized by the right employment of heat and moisture. By cooking, also, food is rendered to some extent sterile and can be kept longer before consumption.

It is, nevertheless, well to bear in mind in this connection that considerable diversity of opinion still exists as to whether the interior of large joints ever reaches a sufficiently high temperature to justify the belief that the process of sterilization *is* efficiently performed by ordinary methods of cooking. Investigations show that the index of the thermometer rarely rises above 58° C. (136° F.) in joints weighing 5 or 6 lbs. It is true that a great deal depends on the length of time such a temperature is maintained, but there is evidence that cooking also gives rise to chemical combinations and reactions the products of which may either favour or check the vitality of germs, so that the results of cooking are eminently complex.

Good cooking demands skill, care, forethought and resourcefulness; it is founded upon scientific principles, calls for art in its application, is of great national importance and affects the well-being of human life at every age.

The employment of the right temperature in the cooking of food is both hygienic and economic in its objects and results. Digestibility is sacrificed and extravagance committed where flavour, tenderness and appearance suffer by carelessness in this respect. By the application of dry heat (roasting or baking), when it is regulated to suit the characteristics of the food-stuffs to which it is applied, flavour is developed and digestibility increased.

The experiments show that the influence of temperature when "moist heat" is the medium of cooking is equally potent. This influence must be borne in mind, for example, in making soups, when it is desired to extract the nutritive and gelatinous substances from the meat, and in preparing vegetables; these latter part readily with their mineral salts and flavours unless plunged from the beginning of the cooking process into water at a temperature of 100° C. (212° F.). Neither must it be overlooked when cooking eggs (*see page* 167), where it is important not to coagulate the albumin, but to solidify it into a jelly-like consistency.

Starch in its numerous food-forms profits in digestibility and flavour from combination with fluids at high temperatures, but when it is mixed with fats, for instance, precautions are necessary (1) to avoid the escape into the water of these more costly food principles; (2) to secure that the melting fat shall not so surround the starch grains that they cannot absorb sufficient water to swell and soften while cooking; and (3) that the fats are not exposed to a temperature sufficiently high to decompose them and render them indigestible.

Heat penetrates food but slowly, as all foods are bad conductors. If heat be applied too rapidly, therefore, fuel is wasted, the outer layers of the meat will be overcooked and the inner layers underdone.

Stress must be laid upon the different results which attend (1) the application of a high temperature for a short time to articles of food, (2) those which follow their exposure for a prolonged period to the influence of a lower degree of heat, or (3) those which are associated with subjecting food-stuffs to some preliminary treatment before the actual cooking by heat begins, for all these are matters distinctly affecting the hygiene of daily life.

For example, the ordinary *milk pudding* is unappetizing, often distasteful, frequently wasted, when baked quickly in a

very hot oven. The same materials when cooked for four or five hours in a slow oven become attractive in appearance, appetizing in flavour and can be consumed without a particle of waste. Again, meat which for some reason is known to be tough, as, for instance, freshly-killed beefsteak, should be well beaten before cooking, a process which bruises and breaks the muscle fibres, renders the meat more tender and promotes its more complete mastication; or such meat may be soaked for some hours prior to cooking in a mixture of vinegar and water, in which case the acid serves as a partial solvent of the tough connective tissue which surrounds the muscle fibres, so rendering them more accessible to the digestive juices when cooked.

II.—The Effects of Cooking upon Meat, Eggs, Farinaceous Foods, Vegetables, Water, Fat, Food Combinations.

MATERIALS: *Raw meat; 1% osmic acid solution; water; filter paper.*

APPARATUS: *Beakers; test tubes; slip of glass; balance; sharp knife; thermometer; sand bath; Bunsen burner.*

(*A*) *Meat.*

(1) (*a*) Shred 28 grams (1 oz.) of fresh, raw meat into a beaker of cold water and place it on a sand-bath. Support a thermometer in the beaker and heat the contents gradually over a Bunsen burner.

Notice whether any coagulation indicates the presence of albumin, and at what temperature this takes place. Also observe carefully whether the surface of the water remains clear as the temperature increases.

Remove the thermometer, cover the beaker with a slip of glass and let the meat simmer gently for some minutes at a temperature not above 80° C. (176° F.). Take it out and examine the aroma, the colour and the consistency of the muscle fibres. Can the latter be separated more easily than before cooking, and is the scent of the meat more appetizing?

(*b*) Repeat (*a*), but instead of shredding the meat, place it in the beaker without division. Are the results similar in the two experiments?

(2) (*a*) Take four small, thick pieces of fresh, raw, lean beef (i.), (ii.), (iii.) and (iv.)

Weigh (i.), cut it into smaller pieces and place them in a beaker with just sufficient cold water to cover the meat. Set aside for fifteen minutes, then pour the liquid into a test tube and boil. Observe the changes that occur in the liquid as regards colouring and coagulation of the albumin.

Weigh the meat; is any loss of weight perceptible? Set aside the liquid to cool; is there any appearance of fat on the surface? Remove the cake of coagulated matter and warm it in a test tube. Allow a drop to fall on filter paper, and test the remainder with 1% osmic acid solution. Do these tests afford evidence that fat was present in, or has been extracted from, the meat?

(*b*) Place (ii.) in a beaker and cover it with boiling water. After two or three minutes take it out and cut it through with a sharp knife.

Observe the effect of the boiling water both on the exterior and on the interior of the meat as regards colour, juiciness and tenderness when cut. Notice also whether the water is more or less discoloured than in (i.).

(*c*) Weigh (iii.) and place it in a test tube; add boiling water and boil for ten or fifteen minutes. Take out the meat, reweigh it and compare it with (ii.) and (iv.) as to texture, appearance and flavour. Has weight been lost or gained in the cooking process?

(*d*) Place (iv.) in a large test tube, add boiling water, and boil for about two minutes; this will coagulate the albumin on the exterior of the meat. Then add a little cold water and simmer on a sand-bath gently

for about 5 minutes, at a temperature not exceeding 75° C. (167° F.). Strain away the water and cut the meat as in (*b*). Compare flavour, consistency and appearance with (i.), (ii.) and (iii.).

NOTE.—"If a piece of lean meat be placed in cold water of which the temperature is gradually raised it will be observed that the water will become slightly red, then cloudy, yellowish, and finally clear when a scum rises to the surface; during this process some of the organic salts and the flavouring matters will be dissolved out. Also small portions of lactic acid are formed during the process, which change otherwise insoluble matters into soluble forms, so that a further loss of nutrients results. The extent of this action and the actual loss by solution depend upon the amount of surface exposed to the water, the temperature of the water, and the length of exposure to heat.

"If the water is heated gradually, more and more of the soluble materials are dissolved out. At a temperature of about 134° F. (57° C.) the soluble albumin will begin to coagulate, and at 160° F. (71° C.), the dissolved albumin will rise as a brownish scum to the surface and the liquid will become clear. Upon heating still higher, the connective tissues begin to be changed into gelatin and are partly dissolved out, while the insoluble albuminoids are coagulated. The longer the action of the water continues, the tougher and more tasteless the meat becomes, but the better the broth. Treated in this way flesh may lose over 40 per cent. by weight. This loss is principally water, but from 5 to 8 per cent. may be made up of the soluble albumin, gelatin, mineral matters, organic acids, muscle sugar, and flavouring materials. Part of the melted fat also goes into the broth.

"It would be a great mistake to assume that the nearly tasteless mass of fibres which is left undissolved by the water has no nutritive value. This tasteless material has been found to be as easily and completely digested as the same weight of ordinary roast meat. It contains nearly all the proteid of the meat, and, if it is properly combined with vegetables, salt and flavouring materials, makes an agreeable as well as a nutritive food.

"If a piece of meat is plunged into boiling water or very hot fat, the albumin on the entire surface of the meat quickly whitens and coagulates, and the enveloping crust thus formed resists the dissolving action of water and prevents the escape

of the juices and flavouring matters. Cooked thus, the meat retains most of its flavouring matters and has the desired meaty taste. The resulting broth is correspondingly poor.

"In boiling sections of delicate fish, as salmon, cod, or halibut, the plunging into boiling water is objectionable because the motion of the boiling water tends to break the fish into small pieces. Fish should be first put into water that is on the point of boiling. The water should be kept at this temperature for a few minutes and then allowed to fall to 180° F. (82° C.), as in the case of meats.

"In stewing, the meat should be cut into small pieces, so as to present relatively as large a surface as possible, and, instead of being quickly plunged into hot water, should be put into cold water in order that much of the juices and flavouring materials may be dissolved. The temperature should then be slowly raised until it reaches 180° F. (82° C.), where it should be kept for some hours. Treated in this way, the broth will be rich and the meat still tender and juicy.

"If the water is made much hotter than 180° F. (82° C.) the meat will be dry and fibrous. It is true that if a high temperature is maintained long enough the connective tissues will be changed to gelatin and partly dissolved away, and the meat will apparently be so tender that if touched with a fork it will fall to pieces. It will be discovered, however, that no matter how easily the fibres come apart, they offer considerable resistance to mastication. The albumin and fibrin have become thoroughly coagulated, and while the fibres have separated from each other the prolonged boiling has only made them drier and firmer."—(U.S. Department of Agriculture, Farmers' Bulletin, No. 34. "*Meats: Composition and Cooking*," *by Chas. D. Woods.*)

Boiling or steaming is the mode of cooking most in use for vegetables because it dissolves gummy and saccharine materials, as in potatoes and carrots, expels the volatile oils that so many contain (*e.g.*, onions), renders leafy vegetables, such as cabbages, greens and spinach, more digestible, and destroys parasites, perhaps also disease germs, though this depends on the length of the process and the temperature maintained. The cellulose, so abundant in vegetables and fruits, is the great obstacle to be overcome in cooking. Chopping and straining are resorted to to assist in dividing this cellulose, but the general habit of shelling

peas and beans, or of peeling potatoes and apples, for example, testifies to the inability of reducing some of these cellulose tissues to any degree of digestibility even by heat and moisture.

Fresh-water fish, and generally all small fish such as whitebait and smelts should be fried by sudden exposure to a very high temperature, which prevents any escape of soluble substance by instantaneously coagulating the proteids on the surface, while the cooking process is very rapid owing to the immersion of the whole object in fat at a temperature of from 176° to 200° C. (348° to 392° F.).

Stewing holds an intermediate place between boiling and roasting. It is the most delicate and secure mode of rendering meat tender, juicy and sapid. It allows of the possible combination of a number of different articles both animal and vegetable, and permits otherwise flavourless food to be made tasty. It is the best method of using tinned meats.

A word of warning should be given on the subject of *meat juices* and *beef tea*. These consist almost entirely of the extractives or flavouring matters present in meat; they are therefore destitute of nutritive principles, and starvation would ensue if the attempt were made to sustain life on such preparations. They are valuable in certain forms of illness, where their appetizing flavours usefully supplement a milk diet, and they occasionally furnish the salts of meat when meat itself is undesirable, but no dependence for actual nourishment must be placed upon even the stiffest jelly into which home-made beef tea may set, "*Beverages*" *III.* (*B.*), (*vide infra*). In common with the many forms of prepared meat juice on the market, beef tea must be considered as refreshing and an appetizer, but not as a nutritive; it is used with advantage for these ends in cases of fatigue or weakness, or when light diet is recommended for a short period, and often seems to exercise some undefined stimulating influence upon the whole system.

(8) *Examination of Meat Extracts for Proteids.*

(1) Prepare 56 c.c. (2 ozs.) of various *meat extracts* in accordance with the directions given on the bottles and label each with a number.

(2) Take an equal quantity of egg albumin solution (*page* 186) and flavour it with a very small quantity of one form of meat extract.

Test each sample for proteid by the xanthoproteic test (*page* 168) and compare results.

How do these agree with the remarks on *page* 292?

(*B*) *Eggs.*

MATERIALS: *Eggs; water.*

APPARATUS: *Small saucepans with lids or large enamelled mugs; slips of ground glass; thermometer; basin; fork; retort stand; Bunsen burner.*

(1) Prepare three small saucepans or large enamelled mugs (*a*), (*b*) and (*c*).

(i.) Put a fresh egg in (*a*), cover it with boiling water, put on the lid of the saucepan or cover with a slip of ground glass. Set it aside for ten minutes; then take the temperature of the water and remove the egg.

(ii.) Pour boiling water into (*b*), then drop in a fresh egg gently, and continue the experiment as in (*a*).

(iii.) Put a third egg into (*c*) after half filling the vessel with boiling water, and maintain the temperature at 100° C. (212° F.) for ten minutes.

Open the eggs and judge in which case the yolk is most appetizing and the white most tender and digestible.

NOTE.—Each egg has cooked for ten minutes, the temperature ranging from 76·5 C. (170° F.) or 85° C. (185° F.) to 100° C. (212° F.). In (*a*) the white will be coagulated, the yolk uncooked and the egg poor in flavour. In (*b*) the albumin will be jellied, the yolk somewhat thickened and the flavour appetizing, though the high temperature will have coagulated the exterior a little too much. In (*c*) the albumin will be hard and less digestible, but the yolk will be well cooked. The yolk contains a large amount of oil, hence the proteid is less susceptible to the coagulating effects of heat owing to the presence of so much fat.

These experiments are planned to impress their lessons by the introduction of the *time element*, otherwise an even better way of cooking an egg than (*b*) is to put it into cold water and bring this to the boil, when the egg will be ready for eating.

The digestibility of cooked egg albumin depends largely upon the extent of subdivision. The white of a hard-boiled egg when chopped and taken with water is shown by numerous experiments to be as completely and as quickly digested as when lightly cooked or even raw; though in general the digestibility of eggs is dependent upon the method employed in cooking them.

(2) Break a fresh egg into a basin, taking care to keep the yolk separate and unbroken.

Whisk the white to a stiff froth with a fork or small bunch of twigs. This process ruptures the walls of the cells in which the proteids present in the egg albumin are enclosed. They escape, and the digestibility of the substance is thereby increased, as the proteids are rendered more accessible to the action of the digestive juices. (*See Fig.* 64, *page* 327.)

NOTE.—The nutritive value of eggs lies chiefly in their contained proteids and fats (*Fig.* 64); one hen's egg yields about 70 small calories, and is the equivalent of 112 c.c. (4 ozs.) of good milk or of 42·5 grams (1½ ozs.) of meat fat. Eggs are very completely absorbed in the intestine, from which, coupled with the amount of lime they contain, arises their constipating tendency, which is partly corrected in the normal diet of healthy persons by the custom of eating bread or other less well absorbed food in combination with them.

(*C*) *Farinaceous Foods.*

MATERIALS: *Potatoes; cornflour; granulated sugar; starch; butter or lard; rice; coarse oatmeal; salt; several varieties of bread; milk; iodine; water.*

APPARATUS: *Beakers; test tubes; large funnel; glass rod; china bowl; enamelled mug or saucepan; balance; Bunsen burner.*

(1) (*a*) Cut a potato in halves, and rub the two portions together over a basin, letting a gentle stream of water drop upon the potato during the rubbing. Collect this water in a glass, and observe that a deposit gradually falls to the bottom. Stir the liquid, and place a small quantity in a test tube; test it for starch with iodine.

Boil a further portion of the liquid and repeat the test. Is any evidence afforded of a change having been brought about by exposure to heat?

(*b*) (i.) Pour 25 c.c. of boiling water upon 5 grams of cornflour, stirring all the while. Break open one of the lumps which form; is the interior cooked and creamy, or hard and little changed?

The result shows that this method should not be employed when cooking starch foods of which the object is to convert the starch into a more soluble form.

(ii.) Repeat the process, but carefully mix 10 grams of granulated sugar with the starch (from i.), before stirring in the water. Observe that the grains of sugar by separating the starch granules give them room to swell and burst.

Or, Weigh out two portions of cornflour (i.) and (ii.), each of about 14 grams ($\frac{1}{2}$ oz.) in weight.

Mix the contents of (i.) into a cream with cold water and stir it into 250 c.c. (nearly $\frac{1}{2}$ pint) of hot milk in a small pan or beaker. Cook it over a Bunsen burner until the mixture boils, then remove the source of heat and pour the cornflour into a china bowl.

At the same time place (ii.) in a small pan and pour over it 250 c.c. (nearly $\frac{1}{2}$ pint) of hot milk and proceed as with (i.).

Compare the consistency and flavour of the two portions. Parts of (ii.) will be in lumps, which if broken open will be found uncooked in the interior, whereas (i.) will be smooth and evenly cooked throughout.

(iii.) Mix 10 grams of starch with 10 grams of butter or lard. Add 25 c.c. of cold water and boil, stirring until the mixture thickens.

Compare the results with (i.) and (ii.).

NOTE.—The digestibility of starch depends upon the rupture of the cellulose envelopes which surround the starch grains. This process is effected by heat, by the action of dilute acid or saliva, or by the amount of moisture present.

One cause for the indigestible character of pastry lies in the intimate combination of raw dry flour with lard or butter which interferes with the swelling and rupture of the starch cells, as the fat encloses the granules in oily envelopes and has little moisture to give off to swell the cells. The necessity for the addition of water to secure the expansion of the starch grains is illustrated in (*b*) (iii.); compare the glutinous character of the mixture when cooked with the consistency of well-made pastry.

(2) Weigh 14 grams (½ oz.) of rice, pick it over and wash it in cold water.

Put 250 to 300 c.c. (about ½ pint) of water in an enamelled mug or saucepan and raise to boiling point over the Bunsen burner. Drop in the rice slowly, and stir gently with a glass rod if the grains settle to the bottom of the vessel. Maintain the water at boiling point for about 20 minutes, leaving the pan or mug uncovered. When the grains can be crushed between the fingers, turn them into a large funnel to drain; rinse the rice with hot water and place it in a dish of known weight. Weigh the whole; what increase of weight has taken place in the rice and what other changes are to be noted as a result of cooking?

NOTE.—To render them digestible is the primary object in the cooking of farinaceous foods and cereals. Starch grains are very close and compact in texture because they are prepared for storage by the plants from which they are derived during seasons of cold and drought. The chemical changes necessary to their digestion cannot take place unless they are first swollen and distended by water. Hydration is thus one of the first changes undergone during cooking, by rice, oatmeal, or other cereal foods, which process may increase their bulk twenty-five fold. An abundance of water must therefore be provided, unless, as in the potato, the amount necessary to enable the starch grains to swell is supplied within the vegetable itself. (*Fig.* 70, *page* 335.)

The rice is washed and rinsed in the course of cooking to remove any loose starch that would be liable to make the grains stick together when heated; and the water is kept bubbling rapidly in order that, by its motion, the grains should be kept separate, and be individually exposed to hydration at a high temperature.

It is well to recall Prof. Atwater's reminder as to the false impressions people are liable to form if they do not qualify, in the light of experience, the information gained by a study of any Table setting forth the composition of food-materials (*p.* 282). "Rice," he writes, "consists of about seven-eighths, and potatoes of only one-fourth, nutritive materials. The first inference is that rice is three times as nutritious as potatoes. In one sense this is true, that is to say, a pound of rice contains more than three times as much nutrients as a pound of potatoes. But if we take enough of potatoes to furnish as much nutritive material as the pound of rice, the composition and nutritive value of the two will be just about the same. In cooking rice we mix water with it, and may thus make a material not very different in composition from potatoes. By drying the potatoes they could be made very similar in composition and food-value to rice. Taken as we find them, a pound of rice and 3½ pounds of potatoes would contain nearly equal weights of each class of nutriments and would have about the same nutritive value." The length of time required for cooking farinaceous foods must be taken into account when estimating their cost, for only by prolonged exposure to heat can they be made wholesome and well-flavoured.

(3) Weigh two portions of coarse oatmeal (i.) and (ii.) each of 28 grams (1 oz.). Soak (i.) for at least 12 hours in cold water, then drain off the water.

Prepare a small pan of boiling water, to which a little salt has been added. There should be at least four times as much water by weight as oatmeal after the latter has been soaked. Stir the soaked oatmeal quite gradually into the boiling water and cook until thoroughly soft and tender, by which time all the water will be absorbed.

The vessel containing the oatmeal should be stood inside a second of a larger size in order to avoid the risk of burning. This larger vessel should be one-third full of

boiling water which must be kept at boiling point. One cover should be placed over the two vessels, the whole forming what is known as a "double boiler."

More boiling water must be added from time to time, if necessary, to keep the outer vessel one-third full. By this method of cooking the oatmeal does not require stirring, does not dry, does not adhere to the vessel in which it is boiled, and is evenly cooked.

Prepare a second pan two-thirds full of boiling water. Throw in the second portion of (unsoaked) oatmeal (ii.) and boil for as long a period as (i.).

Compare the contents of the two pans in regard to consistency, flavour, and other evidences of successful cooking.

NOTE.—Oatmeal requires to be very thoroughly cooked in order to soften the cellulose which it contains, otherwise the nutritive constituents will be but poorly absorbed.

Porridge made from "rolled oats," even when taken in considerable quantities, is better absorbed, the great pressure to which the grains are subjected ruptures the cell walls, breaks down the cellulose, and, by the coincident partial cooking, alters the fat in such a way that it is less liable to become rancid.

To soak cereals in cold water saves time in the subsequent cooking. Steaming, as in the double boiler, is preferable to boiling and obviates the necessity for stirring, which is not desirable for coarse, flaky cereals, though advantageous for those which are fine and granular. Rolled grains require but twice their bulk of water, because of the partial cooking to which they have been already subjected.

The following table gives the temperatures at which the different kinds of starch gelatinize when exposed to moist heat:—

Potato	65° C.	149° F.
Barley	80° C.	176° F.
Wheat	80° C.	176° F.
Rye	80° C.	176° F.
Rice	80° C.	176° F.
Oats	85° C.	185° F.

(4) *Bread* (after Dr. R. Hutchison).

Compare specimens of several varieties of bread, *e.g.*, fancy, household, brown, milk loaves, etc., and judge of their qualities by the characteristics selected by bakers, viz.:—

Crust, thin, flinty, of medium colour, which cracks when broken.

Crumb, of elastic consistency, texture uniform, no large holes, "pile" smooth and silky, creamy-white in colour.

Flavour and *odour*, sweet and nutty.

NOTE.—Mrs. Ellen H. Richards, when writing upon the ideal bread for daily use, considers it should fulfil certain dietetic conditions.

"(1) It should retain as much as possible of the nutritive principles of the grain from which it is made.

"(2) It should be prepared in such a manner as to secure the complete assimilation of these nutritive principles.

"(3) It should be light and porous, so as to allow the digestive juices to penetrate it quickly and thoroughly.

"(4) It should be especially palatable, so that one may be induced to eat enough for nourishment.

"(5) It should be nearly or quite free from coarse bran, which causes too rapid muscular action to allow of complete digestion. This effect is also produced when the bread is sour."

The process of bread-baking is both chemical and mechanical. *Carbon dioxide* is liberated by the action of the yeast upon a sugar present in the flour, and causes the dough to assume a sponge-like consistency as its substance is permeated by the bubbles of gas; the brown colouration of the crust is caused by the formation, from the flour, of substances analogous to *dextrine* and *caramel* (*page* 299) as a result of the high temperature to which the exterior of the loaf is exposed. This temperature is necessary to kill the yeast, to expand the carbon dioxide gas, to render the starch soluble (*pp*. 293-4), to stiffen the gluten and to form the crust.

The mechanical process of kneading is designed to render the dough elastic, and to secure that the gas bubbles shall be broken up into small portions, and evenly distributed throughout the mass, so producing a loaf of even texture.

(*D*) *Vegetables.*

MATERIALS: *Carrot; turnip; potatoes; nitric acid; iodine; Fehling's solution; water.*

APPARATUS: *Beakers; test tubes; sharp knife; Bunsen burner.*

(1) Take two large test tubes or small beakers (*a*) and (*b*). Cut up a carrot and a turnip into large pieces; put the carrot in (*a*) and the turnip in (*b*). Cover both with cold water and boil until the vegetables become soft. Strain off the liquid, and divide the filtrate from each vessel into three portions (i.), (ii.) and (iii.) (*Fig.* 71, *page* 340).

Test (i.) for the presence of albumin by the addition of a few drops of strong acid (IX.—"GENERAL CONSTITUENTS OF THE BODY," I., (*B*), (2), *page* 167). Test (ii.) for starch with iodine (*page* 173). Test (iii.) for sugar with Fehling's solution (*page* 174).

Repeat the above, but place the pieces of vegetable in boiling water. When soft, strain off the liquid, cool, and test as before.

(2) Repeat (1), but mince the vegetables used in each experiment.

NOTE.—Turnips contain practically no proteid or starch, their carbohydrates being present as "pectose bodies." Carrots are far more nutritious, being rich in sugar (10%), and though the amount of proteid is insignificant, their mineral salts are valuable.

The result will show, (1) that root vegetables should be cooked in boiling water in order to preserve what nutritive constituents they possess. (2) That if such vegetables cannot be cooked whole the pieces should be as large as possible, unless it is proposed to use the water in which they are cooked. (3) That only just enough water should be used to keep the vegetables from burning. (4) That the time required to cook any given vegetable depends upon its age, size and freshness.

(3) Take two potatoes (i.) and (ii.). Peel (i.) and soak in cold water, and cook both potatoes as directed in (*E*) (2) (*c*).

Scrape a small quantity from the surface of (i.), peel (ii.) and scrape off a similar quantity of the exposed surface. Divide each portion into three; moisten with a little cold distilled water, and test respectively for the presence of proteid, starch, and sugar. (IX.—"GENERAL CONSTITUENTS OF THE BODY," *pp.* 168-175.) (*Fig.* 70, *page* 335).

NOTE.—It is estimated that if a bushel of potatoes were peeled and soaked before cooking the loss of nutrients would almost equal 500 grams (1 lb.) of beef steak. The richer the potato in proteid the more waxy it becomes when cooked, in consequence of the coagulation of the albuminous substances. This explains the difference in consistency between "new" and "old" potatoes when cooked, as the former contain more juice than the latter, and the proteid is present in the juice. The fibro-vascular layer immediately beneath the rind is richer in mineral matter and proteid than is the flesh, so that, in careless peeling, these valuable ingredients are very generally lost. Thus the nutritive value, as well as the composition of potatoes, may be seriously modified by cooking. The amount of starch or water present is rarely affected, but may be diminished under some conditions by passing out into the surrounding water. Potatoes therefore are preferably cooked in their skins. The starch grains can swell and soften equally well when this means is adopted of preserving the nutritive principles, in consequence of the high percentage of water present in the tuber.

(*E*) *Water.*

MATERIALS: *Potatoes; cloths; blotting paper; water.*

APPARATUS: *Beakers; test tubes; c.c. measure; slip of ground glass; thermometer; plate; shallow basin; enamelled mugs or saucepans with lids; knitting needle; wire gauze; retort stand; air-oven; Bunsen burner.*

(1) (*a*) Three parts fill a small beaker with cold water, place it over a Bunsen flame, and watch the various stages of heating.

Take the temperature when the first tiny bubbles form, rise rapidly, and break on the surface. Continue the heating process for some

minutes after boiling point has been registered. Does the temperature rise above 100° C. (212° F.) as the water "boils faster"?

NOTE.—The tiny bubbles first observed as the temperature of the water is raised are caused by the expulsion of the air dissolved in the water. These air bubbles are succeeded by the much larger steam bubbles, into which form of invisible gas water is changed as its temperature rises. These also rise to the surface, and in their turn are cooled and reconverted into water, *i.e.*, condensed. This stage, when bubbling takes place just below the surface, is described as simmering. If the temperature be further increased the steam bubbles reach the surface and escape in clouds of steam. This is the boiling point of water 100° C. (212° F.), at the ordinary atmospheric pressure of 15 lbs. to the square inch. Since water cannot be made hotter than boiling point at ordinary atmospheric pressure, it is useless waste to consume more fuel than exactly suffices to maintain this temperature.

(*b*) Continue to simmer the water until it is completely evaporated; is any residue left? How would this affect a vessel used constantly for cooking purposes or for the boiling of water, for example, a tea kettle, if the residue were allowed to accumulate.

(*c*) Fill a small beaker with cold water and drop in tiny shreds of blotting paper. Arrange it on a piece of wire gauze on a retort stand. When the water has become nearly still, light the Bunsen burner beneath the flask. Watch the behaviour of the shreds of paper as the temperature rises. How do these "convection currents" explain the reason why large portions of meat or other food-stuffs are cooked equally throughout when immersed in a large pan nearly full of water?

NOTE.—It is often forgotten that cooking processes require water as much as fire or heat, and this in spite of the high percentage of water present in most food-stuffs; more water must usually be added or cooking is impossible. Boiling, steaming and stewing are all variations of cooking food in water.

The fact is rarely realized that, under ordinary conditions, the temperature of food cooked in water cannot be raised above the boiling point of water; this point is usually constant at sea-level, but becomes lower at high altitudes owing to diminution of the atmospheric pressure. Consequently to "boil fast" is a waste of fuel, no higher temperature resulting as is demonstrated in (*a*).

Experiment (*b*) is included as a reminder of the need for constant attention to details of cleanliness in cooking. In (*c*) ocular demonstration is offered of the circulation of currents in the process of heating water; the hotter water rises up the middle of the beaker while an indraught of colder water takes place from the sides and upper surface, thus the article to be cooked receives equal heat on all sides.

(2) (*a*) Measure 50 c.c. of water into (i.) a large test tube, (ii.) a shallow basin. Set both vessels on a hot sand-bath or in a suitable place, well exposed to the air and sun. Note the time required in each case for the water to evaporate.

(*b*) Measure 50 c.c. of water into two basins of similar shape and capacity. Cover one and support both over a Bunsen flame. In which does the water first reach boiling point and from which does it evaporate most rapidly when a high temperature is maintained for 20 minutes?

NOTE.—Another important factor in cooking is *evaporation*, the rapidity of which depends not on the amount of water in the pan or kettle, but on the temperature, on the surface exposed to the air, and on the presence of a current of air. Such air currents increase the rapidity of evaporation by removing the steam as fast as it is formed. On the other hand, if hot air, saturated with moisture, be enclosed in a heated chamber, such as an oven, evaporation is much hindered, though assisted by adequate ventilation, which of course promotes circulation of the air. The skill of a cook is displayed by choosing deep utensils with relatively small superficial areas where prolonged cooking is necessary, whereas when it is desired rapidly to thicken a sauce or a syrup free evaporation is promoted by the use of a broad, shallow vessel.

(*c*) Wash and weigh two small potatoes (i.) and (ii.); so far as possible they should be of the same size. Place them respectively in two enamelled mugs, three parts full of boiling water and cover the mugs.

Boil (i.) vigorously for fifteen or twenty minutes. Allow (ii.) to simmer at a temperature of about 80° C. (176° F.) for the same length of time. When both potatoes are sufficiently soft to be pierced with a knitting needle, drain off all the water from each mug, shake the contents gently, cover the mug with cloths folded in several thicknesses and stand aside for a few minutes.

Then place the potatoes on a plate and compare their consistency, appearance and flavour. (i.) will be more or less sodden, (ii.) will be mealy and dry.

NOTE.—Two facts are illustrated in (*c*). (1) The temperature of the water should be adapted to the food-material to be cooked in it, for rapid boiling in water is liable to disintegrate foods; meats are reduced to unpalatable rags, potatoes become pulpy and sodden. (2) It is not necessary that water should bubble vigorously in order to ensure that food is being cooked.

Vegetables containing woody fibre, such as carrots and parsnips, require the boiling point of water, whereas vegetables with less cellulose and all albuminous foods, require a lower temperature. When water is used to extract juices from meats or flavours from vegetables divide the article into small pieces, so as to expose the largest possible surface to the water, soak these in cold water, heat slowly and never raise the temperature to boiling point. When, on the contrary, water is used merely as a medium for heat, raise it to boiling point before introducing the food-stuffs, which will lower the temperature to about 80° C. (176° F.). The sealing up of the pores in meat or fish will even then not be sufficiently rapid to avoid the loss of some solids, but comparatively little will be dissolved.

Dr. Hutchison points out that, as regards water, the tendency is for vegetable foods to absorb more when cooked

whereas animal foods lose water as well as salts and extractive matters. These different effects of cooking upon the two classes of foods afford another explanation of the results also exercised by cooking upon their digestibility. Meat becomes more concentrated in the process and more indigestible, while the dilution of the vegetable foods after cooking reduces the demand on the digestive juices.

This too, is one reason why meat which has been cooked more than once is rather difficult of digestion. Not only are its proteids apt to be coagulated, but the relative proportion of fat is increased at the same time and both of these facts militate against rapid and easy digestion. On the other hand the increase of bulk which vegetable foods undergo as the consequence of taking up water in the course of cooking is apt to throw a strain on the mechanical, as opposed to the purely chemical, functions of the digestive organs. (*"Food and Dietetics," Chapter* XIV., *by Dr. R. Hutchison* (*Edward Arnold*)).

(3) Boil 500 c.c. (1 pint) of water for twenty minutes, then divide into two portions (*a*) and (*b*).

Set (*a*) aside to cool, pour (*b*) to and fro from one vessel to another five or six times, holding the receiving vessel from 30 to 40 cm. (12 to 16 inches) below that from which the water is poured, so that the water passes through the air; then set aside to cool. Compare the taste of (*a*) and (*b*) one with the other and with an equal quantity of freshly-drawn unboiled water (*c*).

NOTE.—If the manipulation of (*b*) has been efficiently carried out it should taste as "fresh," that is, as fully ærated, as (*c*); whereas (*a*) will taste flat and insipid in consequence of the loss of the dissolved air which occurs during the boiling process; a loss which is repaired by pouring the boiled water to and fro through the air.

Moderately hard water is best for cooking purposes, *e.g.* if tea be made with very hard water the presence of lime salts seems to interfere with the extraction of some of the constituents; if water be too soft it apparently extracts some bitter principle from the leaves. If the water be very hard a pinch of bicarbonate of soda should be added to that used for cooking purposes, or considerable extravagance results.

(*F*) *Fat.*

MATERIALS: *Potato; beef dripping; butter or lard; white bread, water; butter muslin.*

APPARATUS: *Funnel; thermometer; small jar; porcelain basins small spoon; enamelled mugs or pans; air-oven Bunsen burner.*

(1) *To prepare Fat for Cooking Purposes.*

(*a*) Cut some beef dripping into small pieces, put these into an enamelled mug or pan, just cover with cold water and arrange on a sand-bath over a Bunsen burner.

(*b*) When the fat is melted and the water has practically all evaporated, strain the contents of the pan through butter muslin, squeezing them well against the sides of the funnel. Receive the fat into a clean pan or mug stood in hot water, so that the fat remains liquid.

(*c*) Cut two or three slices of raw potato, add to the melted dripping, and heat it slowly in the air-oven until it ceases to bubble. Remove and again strain the fat through butter muslin into a small jar; set it aside till solid, when it is fit for use.

NOTE.—The potato absorbs some of the impurities present in the dripping, and the remainder settle to the bottom of the pan. Caution the pupils not to stir the strained fat, or it will absorb moisture from the air. Impress the food-value of fat prepared in this way, when it can be used as a substitute for butter on hot toast, for making cakes or puddings, and for frying purposes.

The cost of butter and cream is a frequent cause for a deficiency of fat in the diet of the less prosperous classes, who, from ignorance, often waste the fat of beef, which, prepared with a little care and at a small expenditure of time and fuel, constitutes a valuable adjunct to the diet.

(2) (*a*) Put a little butter or lard in a porcelain basin over a Bunsen burner. Take the temperature as the fat foams and bubbles.

(*b*) Continue heating until no more bubbles appear. Again take the temperature, is it higher than in (*a*)?

NOTE.—Fats generally speaking burn before they boil. The bubbles indicate the escape of the water contained in the fat, which occurs at the boiling point of water, or a little higher. After the water has boiled away the temperature of the fat rises rapidly to 150° C. (302° F.), or to 205° C. (401° F.), and in the case of olive oil to as much as 315° C. (599° F.).

(3) (*a*) Raise some lard to bubbling point in a porcelain basin, drop in a small cube of white bread. Remove this after one minute with a small spoon.

(*b*) Continue to heat the lard until it smokes but is perfectly still. Drop in a second piece of bread for the same length of time, remove as in (*a*). Break open both cubes of bread and compare their appearance and consistency.

NOTE.—It is shown in (*a*), (i.) that unless fat used for frying is hot enough to form a crust on the food cooked in it, it will soak into the food and make it greasy, unappetizing, and indigestible; (ii.) that bubbling fat has not attained a sufficiently high temperature for frying purposes; and (iii.) that anything which cools the fat will be liable to bring about the undesirable greasy condition.

One reason why articles of food are usually covered with egg and crumbs before frying is to protect them from absorbing fat. Egg is the chosen medium because of the coagulation of albumin which occurs instantaneously at the high temperature required to heat the fat, and the coagulated albumin forms an impervious envelope round the fish or other foodstuff which it is desired to cook. Batter is employed to surround oysters, for example, when fried, because these highly albuminous morsels are so protected by the water in the batter that the temperature never rises high enough to coagulate their contents, which consequently retain their digestible qualities.

(*G*) *Examples of Food Combinations; Requirements and Advantages of Cooking.*

MATERIALS: *Eggs; white and coarse sugar; salt; milk; flour; beef suet; cheese; baking-powder; cream of tartar.*

APPARATUS: *Beakers; wide-mouthed bottle; thistle funnel; glass tubing; test tubes; thermometer; basins; china cups; patty pans; flat pan; cork with two holes; board; wooden roller; knife; balance; retort stand; air-oven; Bunsen burner.*

(1) Prepare a small quantity of custard by slightly beating the yolk of one egg in a basin, adding gradually 7 grams (1 dessert-spoonful) of white sugar and a pinch of salt.

Heat (but do not boil) 125 c.c. ($\frac{1}{4}$ pint) of new milk in a small pan. Add it slowly to the beaten egg mixture, stirring steadily but gently all the time.

Turn the mixture into two china cups (*a*) and (*b*). Set (*a*) in a vessel of hot water in the air-oven at a temperature of about 80° C. (176° F.) and bake slowly. When cooked the custard will be solid, smooth, and tender.

To test when the process is approaching completion run a knife into the centre of the mass, if it come out clean the custard is cooked.

Raise the temperature of the oven to 100° C. (212° F.) and put in (*b*). Examine the results after ten minutes. It will be found that the custard is full of holes, or watery and curdled. In the first case the high temperature of the oven will have converted the water in the milk into steam which finally escapes, but leaves behind the holes made in its formation. In the second the process of cooking has been too long and at too high a temperature, and the albumin has coagulated.

NOTE.—If the "scalded" milk be added to the egg and sugar at too high a temperature the albumin in the egg will coagulate and the mixture will "grain" or curdle. In such a case the basin must be at once plunged in a vessel of cold water and

the mixture beaten vigorously with a fork until it becomes smooth. The milk must not therefore reach a temperature above the coagulating point of albumin (*see page* 167).

(2) Make a small quantity of suet pudding mixture as follows:—Sift 112 grams ($\frac{1}{4}$ lb.) well-dried flour in a basin, add a pinch of salt, rub into it 56 grams (2 ozs.) finely shredded, fresh, beef suet freed from skin, and add 56 grams (2 ozs.) coarse sugar. Beat up one egg in a little milk and moisten the suet and other ingredients sufficiently to form a dough.

Divide this into two portions (*a*) and (*b*).

Tie (*a*) into a small cloth made of two layers of butter muslin, put it in a large beaker and cover with boiling water.

Butter a small cup or beaker and fill it nearly full with (*b*), cover the surface of the cup with a sheet of greased paper, securely fastened round the exterior with tape or string.

Place (*b*) also in a large beaker or small pan and surround with boiling water to a depth of two-thirds the height of the cup.

Support the vessels containing (*a*) and (*b*) above a Bunsen flame and boil the water for some minutes. Observe the amount of fat which escapes and rises to the surface in (*a*).

Remove both puddings from the cooking utensils and test by eye and taste the influence of careful and intelligent cooking upon the appearance, flavour and consistency of such a combination of food-materials.

NOTE.—The advantages are clearly demonstrated of "steaming" the pudding mixture within a vessel by which it is isolated from the water and protected by a waterproof covering over merely "boiling" the pudding in a cloth; this latter absorbs and conducts to it the water in which it is being cooked, disturbing the proportions of its ingredients and rendering the mass sodden, unappetizing and indigestible.

(3) *The Influence of Different Combinations on Digestibility.*

Take two pieces of cheese (*a*) and (*b*) about 28 grams (1 oz.) in weight.

Place (*a*) in a patty-pan over a Bunsen burner and cook for 5 minutes. Grate (*b*) finely, mix with half the quantity of baked flour, moisten with milk in which a pinch of bi-carbonate of potash has been dissolved, stir the ingredients into a creamy consistency, pour into a greased patty pan and bake until solidified. Compare the taste and consistency with (*a*).

NOTE.—The addition of bi-carbonate of potash to cooked cheese neutralizes any free acid that may remain in the cheese, and effects a better solution of the casein, often enabling so useful and cheap a food to be well digested, when without this addition cheese has to be excluded from the dietary. The proportion of bi-carbonate of potash estimated by Matthieu Williams as necessary for this solvent purpose is at the rate of about 7 grams (¼ oz.) to a lb. of cheese; no change of flavour is detected, only the digestibility is materially increased. The same authority also advances a physiological reason in support of his advice. He points out that the potash salts so necessary to the well-being of mankind are wanting in cheese. The custom of eating raw salads with cheese largely supplies the deficiency, but where such an addition to a meal of bread and cheese is impossible, on the score of expense or for other reasons, the simple suggestion embodied in the above recipe may be employed with advantage.

A healthy appetite is usually guided by instinct to select appropriate food-combinations, and thereby furnishes approximately the proportions of proteids, carbohydrates, fats, salts and water required by the body. For example, the common practice of eating bread (chiefly carbohydrate) with bacon (proteid and fat), butter and eggs (proteid and fat), milk or soup, offers a familiar illustration of this point. Many more examples could be given, such as eating veal, chicken or rabbit with bacon, or with other foods deficient in fat, or, for the same reason, serving sauce with fish.

(4) *Illustration of Means employed to make Doughs, etc., "light."*

Mix a large pinch of salt with 56 grams (2 oz.) of flour, and divide into two portions (*a*) and (*b*), in two small basins.

Rub 3 or 4 grams of butter into (*a*), and add very gradually about 14 c.c. (1 tablespoonful) of milk, or enough to make a soft dough; use a knife for this mixing process.

Turn the dough on to a board over which a little flour has been sprinkled; roll it lightly with a wooden roller or large ruler till it is about 1·5 cms. (½ inch) thick, cut it into small round pieces and lay these on a flat pan, being careful to grease the surface upon which they are laid.

Proceed to treat (*b*) in exactly the same way, but before rubbing in the butter thoroughly mix 2 grams of baking-powder with the flour.

Place (*a*) and (*b*) in the air-oven at a temperature of 180° to 205° C. (356° to 401° F.) and bake from 10 to 15 minutes.

Which cakes are the lighter and more digestible in consistency?

NOTE.—In order that the principle which underlies the use of various leavening agents may be intelligently understood, it is suggested that the following series of experiments, directed to this end, be carried out by the pupils. These are concerned with the action of baking-powder only, references to the production of carbon dioxide by yeast will be found in XVIII.—"*Beverages*," VI. *F.* (2) (*b*).

(*a*) Recall the result of adding a carbonate to an acid. Direct that a few c.c. of soda-solution be placed in a flask fitted as in *Fig.* 10 and that the long end of the glass tube be immersed in lime water. Compare what follows when vinegar is poured down the thistle funnel with—"*Air*," IV. (*A*) (3), *page* 54 and—"*The Systems of the Body*," IV. (*C*), *page* 152.

(*b*) Dip a slip of neutral litmus paper into a portion of the soda-solution used in (*a*), note the result, then test whether vinegar be an acid or an alkali in the same way.

Proofs are afforded by these observations that when an acid is added to a carbonate in the presence of water carbon dioxide is formed, producing an effervescence similar to that which takes place when hydrochloric acid is added to lime salts (also alkaline).

(*c*) Proceed to add vinegar cautiously to the portion of soda-solution used for the litmus paper test, until the neutral litmus paper shows no change when immersed in the fluid. This condition of "neutralization" always occurs when

exactly the right proportions are used of the different acids and alkalies, that is, each has the property of destroying the characteristic distinction of the other.

(*d*) Make some baking-powder by thoroughly mixing 1 part of bi-carbonate of soda with 4 parts of cream of tartar. Put a few grams of the mixture in two test tubes (i.) and (ii.). Add cold water to (i.) and hot water to (ii.), in which case is the liberation of carbon dioxide gas (foaming) most marked?

Bi-carbonate of soda readily gives off carbon dioxide gas when treated with an acid, and cream of tartar proves the most convenient form of acid to employ in baking-powder because it only acts on soda in the presence of warmth and moisture. It is prepared from the salts which form on the inside of wine casks and the residue which remains when effervescence subsides is practically harmless (it is known as Rochelle salts).

It will be observed that baking-powder when combined with flour, though moistened, is only very slightly active until exposed to heat, then gas comes off readily, the substance of the batter or dough is expanded by the bubbles which form, of which the walls become thinner as their size increases. Just as they reach breaking point the temperature of the oven should be such as to "set" the dough and imprison the gas; this makes the mixture light and porous, so that it is easily penetrated by the digestive juices. If the oven be too hot, the "setting" process takes place at too early a stage, if it be too cool the gas escapes when the bubbles break. In either case the result is heavy cakes or bread. It is usual to add a small proportion of dry starch to baking-powder mixtures, as it serves the useful purpose of absorbing any moisture which may gain access to the soda and cream of tartar; this, if unabsorbed, might start a sufficient amount of activity to diminish the reaction of the powder when exposed to heat in combination with dough.

(5) Give illustrations from familiar articles of food of the advantages, æsthetic or hygienic, which result when food is carefully cooked. For example:—

(*a*) That it becomes more appetizing, *e.g.*, meat, fish or game.

(*b*) More wholesome, *e.g.*, potatoes, oatmeal, etc.

(*c*) More varied in form, *e.g.*, meat when roasted, stewed, grilled, boiled, etc.

(*d*) More varied in flavour. Mention instances of these results.

Show also that by cooking opportunity is afforded for:—

(*e*) The removal of indigestible, damaged, or decaying portions, *e.g.*, the skin of fish, fruit or vegetables, bruises in fruit, the eyes of potatoes, etc.

(*f*) The further development of natural flavours, *e.g.*, coffee.

(*g*) The addition of flavouring substances, *e.g.*, onions to stews, herbs in soups, lemon or vanilla to milk-puddings, blanc-manges, etc.

(*h*) The sterilization, partial or complete, of the article of food, *e.g.*, milk, meat, etc.

NOTE.—One of man's distinguishing characteristics is the fact that he has devised, through cooking, means for making his food more wholesome and varied, in some cases more digestible. Many reasons exist for the general adoption of this habit by the human race, most of which may be grouped under one or other of three main divisions, hygienic, æsthetic and economic.

Foods are usually rendered more attractive to the eye and more palatable to the taste by the different modes of cooking employed, of which results meat offers a familiar illustration, or the ultimate composition of food-stuffs may be affected, as is the case with farinaceous preparations. By means of cooking, combinations also become possible by which the flavour of nutritious principles is increased, as, for example, in soups or stews, where vegetables and herbs give zest to otherwise somewhat tasteless "stock"; or which add to the nutritive value, as when eggs are combined with milk in custards, or with flour in batters, or when cream is cooked with the juice of fruit. Other combinations modify highly concentrated forms of nourishment, as when bread crumbs are cooked with cheese or meat is mixed with potatoes or rice.

Statistics collected by scientific enquirers in the United States testify that it is no exaggeration to say that many thousands of starving people could be wholesomely fed on

food now wasted by careless and bad cooking. The investigations on this subject conducted, for example, by Professor Atwater, brought the following facts to light:—Of the total food bought by a carpenter 7·6% was left in kitchen and table-wastes; this consisted chiefly of proteids and fats, the most costly articles of diet. Analysis of similar waste matters at a boarding-house showed that one-ninth of the nutritive material in the food purchased was simply thrown away, yet the mistress was reputed to be an excellent housekeeper, and erred through ignorance not carelessness. There is much truth in Prof. Atwater's comments on these and many similar revelations. He writes:—"We endeavour to make our diet suit our palate by paying high prices in the market rather than by skilful cooking and tasteful serving at home. We buy more than we need, and what makes the matter worse, it is freqnently those who most need to save that are the most wasteful. The remedy for the evil must be sought in two ways, in an understanding of the elementary facts regarding food and nutrition, and the acceptance of the doctrine that economy is not only respectable but honourable."

It cannot be too strongly impressed that ordinary methods of cooking seldom suffice to kill parasites and to destroy noxious bacteria. In a piece of meat weighing 10 lbs. the temperature of the interior, after boiling four hours was only 88° C. (190° F.). The inner temperature of meat when roasting has been observed to vary from 72° C. (161° F.) to 92° C. (198° F.) according to the size of the joint.

Experiments are included to show that the liberation of carbon dioxide gas makes doughs and batters light and porous, a result obtained by steam alone when a watery batter is cooked at intense heat. When eggs are used to stiffen batters a similar end is attained by the vigorous beating of either the eggs alone or the mixture with which they are incorporated. Fat also "shortens" flour mixtures, the term used to express the result of the separation of the starch grains of the flour by the fat, by which the product is rendered more tender. Necessarily this Section cannot treat in detail all the processes comprehended under the Cooking of Food; it contains only references to some of the more immediately hygienic features.

XVII.—THE STUDY OF MILK AND OF THE FEEDING OF INFANTS.

I.—The Study of Milk.

(*A*) *General Properties of Milk.*

MATERIALS: *Milk; strip of gummed paper; litmus paper (red, blue, and neutral); turmeric paper; water.*

APPARATUS: *Large glass jars; glass tubing.*

(1) Fill a large gas-jar with fresh milk and stand it aside in a cool place for several hours, then observe the colour (a rich, thick, yellowish white), consistency (opaque), flavour (bland or slightly sweet), and odour (creamy). The fluid should have no sediment, neither should it look blue round the edge of the vessel.

(2) Estimate roughly the depth of the layer of cream upon the surface of a specimen of milk. For this purpose take a strip of gummed paper, the same length as the gas-jar which is to receive the milk; divide the strip by folding it into twenty subdivisions. Moisten and then fix this graduated guage to the jar, which must be filled level with the upper edge of the last subdivision on the gummed paper. The milk must rest undisturbed in the gas-jar in a cool place before any observation is made.

Read off the proportion of cream to milk in the jar, according to the number of subdivisions through which the layer of cream extends. If the cream registers a depth of two subdivisions, that is a depth equal to $\frac{1}{10}$ the height of the column of milk in the jar, it is considered average in quality. Under exceptional circumstances the proportion of cream might amount to $\frac{1}{5}$ of the whole, or it may not exceed $\frac{1}{8}$. The amount varies with the season, breed of cattle, fodder and various other causes.

(3) Carefully syphon off the milk into a second clean gas-jar to within 1·5 cm. ($\frac{1}{2}$ in.) of the bottom of the vessel; then refill it by pouring distilled or boiled water upon the small residue and set aside for further treatment (*p.* 384).

(*B*) *Test for the Characteristic Reaction of Fresh Milk.*

MATERIALS: *Milk; litmus paper (red, blue, and neutral); turmeric paper; water.*

(1) Place a drop of fresh milk on a piece of red litmus paper; wash it off with distilled water, repeat the experiment with blue litmus paper. Note the peculiar results, which arise from the fact that fresh milk contains both acid and alkaline salts.

(2) Pour a few c.c. of fresh milk into two small test tubes, (*a*) and (*b*).

(i.) Test (*a*) with neutral litmus paper and (*b*) with turmeric paper. Observe that milk gives an acid reaction to litmus and an alkaline reaction to turmeric.

Set aside the test papers to dry, and preserve for comparison with those used in (ii.).

(ii.) Repeat the test with the milk after it has stood from 24 to 48 hours, at a temperature of from 15° to 20° C. (59 to 68° F.). Are similar results obtained?

NOTE.—It will be observed that no alkaline reaction occurs after sufficient time has elapsed for the decomposition of the sugar in the milk, which change results in the formation of lactic acid. Comparison with the litmus paper used in (i.) (*a*) will demonstrate the marked increase of the acid reaction. The original acid reaction is due to the presence of acid phosphates and dissolved carbonic acid in fresh milk.

(*C*) *Method of Determining the Quality of Milk by means of the Lactometer.*

MATERIALS: *Milk; water.*

APPARATUS: *Gas-jar; thermometer; hydrometer and lactometer; pipette.*

(1) Take a second gas-jar of the same size as that to which the milk was transferred in (*A*) (3), and fill it to the same height with water.

(2) Take the temperature of the water and of the milk in the two jars; it must in each case register 15° C. (59° F.). Insert a hydrometer and a lactometer into each jar respectively, by gently pressing (not dropping it) to the bottom of the vessel before releasing hold of the instrument.

When each is at rest, take notice what division on the stem seems level with the surface of the water and the milk respectively. The specific gravity of normal milk ranges, at the above temperature, from 1·028 to 1·034, while that of water is 1. Should the reading of the lactometer be 1·029 for instance, it would show that the specific gravity of this specimen of milk is 1·029, and presumably the quality is good.

(3) *Possible fallaciousness of this test if uncorroborated by further evidence.*

Set aside the milk used in the above experiment for some hours until the cream has again risen to the surface. Remove the cream by means of a pipette, and again take the specific gravity as in (2). Compare the reading of the lactometer. The specific gravity will have increased, and the reading will vary from 1·032 to 1·035. Can you account for this change in the specific gravity of the milk since it has been skimmed?

(4) Add a small quantity of water to the milk and again test the specific gravity, being careful to maintain the same temperature throughout the experiment. Is the specific gravity of the fluid greater or less than in (3)?

Record as below and compare the results of the test in each case:—

SPECIFIC GRAVITY.—Whole milk .. ..
Milk with cream removed .. ..
Milk to which water has been added..

NOTE.—These tests will clearly demonstrate that if the specific gravity be taken apart from other observations the result is quite misleading as a guide to the true quality of milk.

The specific gravity of rich milk is low in consequence of the presence of at least 10% of its lightest ingredient, cream. When this oily substance has been skimmed off the surface

of milk to which it has been allowed to rise, the specific gravity of the milk is at once raised. But water on the other hand has a lower specific gravity than even the richest milk, consequently if 8% of fat be removed and 2% of water be added the lactometer may still register 1·028, which to the unskilled or careless would be accepted as sufficient evidence of the good quality of the milk, whereas in fact, it is very poor.

Corroborative evidence must therefore be always obtained before reliance can be placed upon the specific gravity registered by a lactometer. Otherwise a milk exceptionally rich in cream might conceivably be classed as watered, while if the cream has been removed and a small amount of water added it might show a normal specific gravity. If, therefore, this test be employed, it must always be associated with the observations carried on in (*C*).

To ensure accuracy, the specific gravity of the milk should be tested at the temperature of 15° C. (59° F.), but if any circumstances prevent this from being done, then for every 3° of deviation from 15° C. and for every 5° of deviation from 59° F., make an allowance of ·001 specific gravity. If the temperature be above 15° C. (59° F.), add the respective allowance to the number actually found; if the temperature be below 15° C. (59° F.) it must be deducted. Thus, if the milk possess a temperature of 21° C. (70° F.) and a specific gravity of 1·028, as the excess of temperature above 15° C. amounts to 6°, and, above 60° F. amounts to 10°, make an allowance of ·002 on account of the temperature, and *add* this to 1·028; as a result 1·030 will be the number expressing its specific gravity at the standard temperature of 15° C. (59° F.).

Again, if the trial be made when the milk is at a temperature of 9° C. or 48° F., and the specific gravity be found to be 1·032, make the allowance of ·002, but *deduct* this from the amount found, and the remainder, or 1·030, will denote the specific gravity.

Although the undue removal of cream from milk is quite properly constituted a legal offence, skim milk is a valuable and cheap source of proteid food for those who combine it with carbohydrates, such as bread, and some fat to make good the absence of cream, such as dripping or butter. For infants, in whose diet fat is a very important factor, skimmed milk is quite inadmissible (*Fig.* 62), while the sale of skimmed milk as

whole milk is an economic fraud, for its market value is about one-fourth. But after infancy, as much heat and energy can be obtained for the body from an expenditure of twopence on skim milk and bread as from five times that amount spent on meat and vegetables.

It is useful to include this demonstration in a study of milk, if only to impress the fact that no one type of test can be relied upon as a guarantee of the quality of milk any more than in the case of water. The public must largely rely for accurate assurance of the qualities of food and drink upon skilled analysts, whose appointment as public officials is a necessary safeguard of the public health.

(*D*) *To determine the amount of dirt in Milk.*

MATERIALS: *Milk (reserved in (A)); filter paper.*

APPARATUS: *Beaker; glass tubing; funnel.*

(*Adapted from "Bacteria in Milk and its Products,"* Conn, Rebman, Ltd.)

Take the gas-jar of milk sediment and water set aside in (*A*) (2) after it has been at rest for several hours. Again syphon off the supernatant liquid to within about 1·5 cm. ($\frac{1}{2}$ in.) of the bottom of the vessel. Re-fill the jar with water as before, and repeat the operation as often as is necessary, that is, until the liquid is practically clear, which will indicate that the sediment has been thoroughly washed.

Filter the clear liquid through moist filter paper, the sediment will thus be isolated and may be carefully dried in the air-oven, when it will represent, with tolerable accuracy, the amount of insoluble filth which found its way into the specimen of milk. It is composed of inorganic dust and of organic matter, shreds of epithelium, hairs, pus, etc.

NOTE.—The weight of such dirt will be a variable quantity according to the material of which it is composed, and the amount will be in an inverse ratio to the cleanliness practised in the cowshed and dairy, the methods of transit and of distribution, etc. It may be as small as 2 mgs. per litre ($1\frac{3}{4}$ pint) or as high as $\frac{3}{10}$, or more, of a gram, though the latter would indicate an excessive amount of dirt.

All dirt should be brushed from the cow before milking, and the udder and flank should then be dampened in order that bacteria and dust may not be shaken into the pail. The hands and clothes of the milker and all the utensils employed should be scrupulously clean, and the milk should be covered from risk of contamination as soon as the milking process is complete.

(*E*) *To illustrate the odour-absorbing properties of Milk.*

MATERIALS : *Milk ; onion, or a piece of pineapple.*

APPARATUS : *Beakers ; c.c. measure ; 2 large bell-jars or 2 tin biscuit canisters.*

Half fill two beakers (*a*) and (*b*) with 50 c.c. of fresh milk. Prepare two large bell-jars or two tin biscuit canisters with well-fitting lids (*c*) and (*d*). Place (*a*) within (*c*) and enclose an onion or a piece of pineapple under the same cover. Enclose (*b*) within (*d*) in similar fashion, but without any onion or pineapple.

Set both tins aside in a cool place for 24 hours; then examine the two specimens of milk as to taste, smell, etc.

NOTE.—The necessity must be impressed for scrupulous care in the keeping of milk when delivered from the dairy. Milk ought always to be distributed in bottles. The cork or seal should not be opened until the milk is actually required for use and, if the whole contents of a bottle are not consumed, the open end should be covered with a slip of clean glass to exclude dirt of any kind from gaining access to the milk.

(*F*) *Milk Curdling and Milk Clotting.*

MATERIALS : *Milk ; rennet.*

APPARATUS : *Beakers ; thermometer ; retort stand ; Bunsen burner.*

(1) Take two glass beakers (*a*) and (*b*). Fill each three-fourths full of fresh milk.

Set (*a*) aside, and keep at a temperature of 20° C. (68° F.) for two or three days. Watch any changes which take place in the appearance, flavour, consistency and odour of the milk.

(2) Warm the contents of (*b*) to rather above body heat 39° C. (102° F.), add a few drops of rennet and keep warm; the milk gradually coagulates, *i.e.*, sets into a jelly-like mass, which separates into a solid clotted curd upon the surface, while a watery fluid collects beneath. Set (*b*) aside in a cool place, and compare the contents with those in (*a*) for the time both are kept under observation.

NOTE.—The changes undergone by milk at ordinary temperature are familiar to all. They are initiated by the various kinds of bacteria present in the milk ducts of the cow or in the air, persons and surroundings with which the milk comes in contact. These micro-organisms may be roughly grouped into *three* classes. Of these, two classes are normally present in milk, those which produce lactic acid and those which produce certain enzymes or chemical ferments, one of which possesses the characteristics of rennet, while another digests or liquefies the casein present in milk; these are known as casein ferments. Under certain conditions, intensely poisonous substances may form in milk, which cause virulent symptoms of poisoning similar to those associated with the consumption of meat, cheese or ice cream, in which they are also liable to form.

The milk in (*b*) first "coagulates" and then "clots," because the ferment *rennin* (a constituent of the gastric juice in the human stomach as well as in that of the calf), brings about some obscure change in milk by which it is converted from a fluid into a solid substance. The *caseinogen* takes on new characteristics and becomes indeed practically a new substance, in consequence of the fundamental alterations it undergoes. When this change is brought about artificially, the product is known as *junket*.

The curds of milk, whether natural or artificial, consist of casein, fat and probably a little lactose, together with the water, milk-albumin, and salts from the whey. Thus, whenever milk enters the stomach it becomes a solid, a change accomplished with greater or less rapidity according to the condition and quantity of the gastric juice.

In (*a*), the series of changes are those associated with the phenomenon not of clotting but of "curdling;" they result from the formation of lactic acid in the milk. No actual chemical change takes place in the caseinogen of

milk when the fluid curdles, it is merely "turned out of its partnership" with lime-salts, and being rendered insoluble it falls down in the form of a flocculent precipitate.

There are many different types of bacteria capable of producing lactic acid in milk, fortunately most of them are killed by exposure to a moderate heat. The souring of milk from this cause is, so Prof. Conn writes, "a well-nigh universal phenomenon." The same authority also points out that these micro-organisms produce other chemical products, dependant in a measure upon temperature. Lactic acid itself is produced from the decomposition of milk-sugar by the agency of these bacteria, most of which grow best at a temperature between 21° C. and 36° C. (70° F. and 97° F.). They probably exist in the hair of the cow and in the air of the stall, as well as in the fodder and the dust. Professor Conn says, "The power of producing acid seems to grow stronger as the bacteria develop in the milk. If bacteria are taken from fresh milk their power of forming acid is rather feeble, but if bacteria are taken from the same milk after a two days' growth, their power of producing acid is noticeably greater. This seems to indicate that they get into the milk from some source where they exist in a dormant condition, and only develop their vigorous powers after growing in milk for some hours. The conditions in the milk stimulate their power of producing acid in marked degree."

(*G*) *Micro-Organisms in Milk.*

Materials: *Milk; nutrient gelatine; labels; water.*

Apparatus: *Petrie dishes; flasks; pipette; test tubes; beakers; c.c. measure; retort stand; Bunsen burner.*

Prepare two sterilized Petrie dishes (*a*) and (*b*), also two sterilized flasks, each to hold 100 c.c. (*c*) and (*d*). Fill (*c*) with cold, well-boiled water and add 1 c.c. of fresh milk by means of a sterilized pipette; shake the mixture thoroughly in order to break up the clumps of bacteria which form in milk. Place two test tubes of nutrient gelatine in a beaker of warm water, in order just to liquefy their contents. Transfer 1 c.c. of the milk and water mixture to one of these test tubes and shake gently, but on no account roughly, in order to distribute the material evenly. Open

(*a*) quickly, pour in the contents of the test tube, immediately replace the cover and rotate gently to form a thin layer over the bottom of the dish. Label at once and set aside. Repeat the procedure with the flask (*d*), but introduce 1 c.c. of milk which has been sterilized or exposed to prolonged boiling. Set both dishes aside, and keep them for three or four days in a dark place at a temperature of 21° C. (70° F.). Examine them in a good light for a few minutes daily, in order to detect the first appearance of any "colonies" of bacteria which may develop on the surface of the gelatine.

NOTE.—Spots on the surface of the gelatine become evident to the naked eye in about two days, and by counting these an approximate idea can be formed of the number of "colonies" present in 1 c.c. of milk. By comparison of (*a*) with (*b*), evidence is afforded of the protective influence exerted by boiling milk. Bacteria are usually so numerous in milk that dilution of the milk with sterilized water is desirable. A higher degree of dilution than that advised in the experiment is necessary if the milk be stale.

For various reasons it has proved impossible to obtain, so far, the absolute number of living bacteria present in 1 c.c. of milk. The number is always underestimated. In exceptionally clean, fresh milk not more than 100 may be present in each c.c. of the specimen tested. Fresh milk from an ordinary dairy usually contains from 300 to 10,000 micro-organisms per c.c., while ten times as many may be present where conditions are bad. The number depends upon care in the dairy, care in transfer, and the temperature at which the milk is kept. Many of these bacteria, however, though significant of carelessness, do not render the milk unwholesome; some produce no distinctive action at all upon the milk; but where through carelessness and ignorance milk is allowed to become highly impregnated with micro-organisms the risks are enormously increased that some among them shall be of a pathogenic type, and capable of carrying the infection of *enteric* or *scarlet fever* or of *diphtheria* to the consumers. In all cases milk should be kept at a temperature of 10° C. (50° F.), or less, from the moment of milking until employed for cooking or other purposes. A low temperature is unfavourable to the development of most of those forms of bacterial life common to milk.

(*H*) *Necessity for Cleanliness in vessels used for Milk.*

MATERIALS: *Milk; soap; soda; water.*

APPARATUS: *Beakers; c.c. measure; slips of glass; retort stand; Bunsen burner.*

(1) Take four small glass beakers, (*a*), (*b*), (*c*), (*d*). Thoroughly cleanse (*a*) and (*b*) with soap and hot water. Leave (*c*) and (*d*) unwashed, and exposed to the air of an occupied room for 24 hours before use.

Place 15 c.c. of boiled milk in (*a*) and (*c*), and cover (*a*) with a slip of clear, clean glass.

Place 15 c.c raw milk in (*b*) and (*d*), and cover (*b*) with a similar slip of glass.

Set all aside for 24 hours in a warm place, and then compare the results in each case on the condition of the milk.

(2) Take two glass bottles (*a*) and (*b*) and place in each 100 c.c. of milk. Empty them of the milk after half an hour. Stand (*a*) aside for subsequent examination. Cleanse (*b*) immediately and thoroughly with soda and boiling water.

Compare the appearance and odour of the two bottles after 24 hours, and test the effect of their relative condition upon milk by again pouring a small quantity of fresh milk into each. Set aside, but keep under observation. Notice the period which elapses in each case before the souring process sets in.

NOTE.—Where curdling of milk has occurred and the vessel is difficult to cleanse great assistance will be derived from the use of a weak solution of permanganate of potash (Condy's fluid), or of soda.

(*J*) *The Preservation of Milk.*

MATERIALS: *Milk; water.*

APPARATUS: *Beaker; small pans; c.c. measure; thermometer; retort stand; Bunsen burner.*

(1) *Boiling of Milk.*

Place 25 c.c. of milk in a small pan (*a*) and an equal quantity in a glass beaker (*b*). Stand (*b*) in a second pan half-full of water, and cover. Raise the temperature of the milk in (*a*) to boiling point. Is the temperature the same as that of boiling water? Boil the water in (*b*). Is the milk in the inner vessel raised to boiling point?

Compare the disadvantages of cooking milk, as in (*a*), when it burns easily and boils over quickly, with the advantages which attend the use of a "double boiler" such as is simulated by the arrangement of the two vessels in (*b*).

NOTE.—In consequence of the importance of milk as an article of diet especially for young children and invalids, and of its great susceptibility to chemical and fermentative changes, care and skill must be directed to the best methods for its preservation; of these a low temperature is unquestionably the best—the milk remains unaltered and retains all its best characteristics.

Preservation by heat (boiling, pasteurization and sterilization), ranks next in order of value, and is the only legitimate method where cold storage or chilling are impossible.

Preservation by the addition of antiseptics is rightly described as "unnecessary, unjustifiable and possibly injurious," especially to infants.

Milk boils at 91° C. (196° F.), but this temperature is not high enough to secure the destruction of every form of pathogenic bacteria which may gain access to it.

Authorities are not unanimous as to the influence of boiling upon the digestibility of milk, though some of the best-known men agree that it becomes slightly less digestible as a consequence.

In the opinion also of some physicians, the nutritive value of milk is diminished when raised to a higher temperature than 68° C. (154° F.).

On the other hand, Dr. Hutchison states that boiled or sterilized milk is not appreciably less well absorbed than the raw fluid, though the habitual consumption of such milk by infants seems to induce a scorbutic condition; that is, such young children become liable to suffer from a peculiar disease of the blood and bones which resembles scurvy, a

complaint by which infants are never attacked when fed on *fresh* milk. The ideal to work for is, no doubt, the production and transport of milk under conditions which will remove the existing necessity, in any case, for sterilizing milk before being taken as food during the susceptible years of a child's early life.

Unfortunately a higher temperature than 80° C. (176° F.) imparts a "boiled flavour" to the milk, while, as has been pointed out, a lower temperature will not ensure protection from disease germs. It is stated on good authority that about 70% of saprophytic bacteria are killed in one hour at a temperature of 60° C. (140° F.); in fifteen minutes at 66° C. (151° F.); in ten minutes at 70° C. (158° F.); in five minutes at 80° C. (176° F.); in two minutes at 90° C. (194° F.); and in one minute at 95° C. (203° F.).

It has not, however, been proved that the bacillus of tuberculosis is destroyed in milk even if exposed for half-an-hour to a temperature of 70° C. (155° F.) neither are the bacteria capable of causing diarrhœa destroyed at this moderate temperature. Complete sterilization is only affected by continuous heating, under pressure, at a temperature of 120° C. (246° F.) for at least two hours. But by this process not only are all bacteria and their spores destroyed, but part of the lactose is converted into caramel, part of the casein is precipitated and rendered more difficult of digestion, the fine emulsification of the fat is destroyed, the lacto-albumin is coagulated, and the normal taste and appearance of the milk are destroyed.

(*K*) *To Diminish the "Boiled Flavour" in Milk and to Prevent Formation of Scum.*

Materials: *Milk; water.*

Apparatus: *Beakers; c.c. measure; slips of glass; water bath; bowl; retort stand; Bunsen burner.*

Take two small beakers (*a*) and (*b*). Place 25 c.c. of raw milk in each beaker and cover with a slip of glass, arrange both in a water-bath over a Bunsen flame. Boil the water in the bath for 10 minutes, then remove the beakers and at once plunge (*a*) into cold water; the water must reach *above* the level of the milk it contains. Stand (*b*) aside to cool.

Note the difference to be observed in the appearance and flavour of the milk in both tubes after half-an-hour.

NOTE.—The sudden decrease of temperature from 80° C. (176° F.) to 10° C. (50° F.), or preferably lower, affects the flavour of milk exposed to pasteurization and sterilization most favourably, as it almost entirely removes the "boiled" taste to which exception is often taken. The treatment can be easily carried out when the milk is to be consumed cold.

"Skin" forms over heated milk in consequence of the rapid evaporation which takes place from an exposed surface, thus chilling the superficial layer of the fluid; when the whole mass is cooled at the same temperature, as by immersion in cold water, this objectionable result is avoided. The "skin" consists of coagulated albumin, all of which (·2 to ·6%) is removed from cow's milk by heat, as well as of some casein and salts of lime.

It will be of great value to supplement this study of milk by a visit to a dairy where the milk is pasteurized or sterilized before distribution. By no better means can the great care necessary to keep milk wholesome be so adequately impressed. Observation will show the importance to be attached to the scrupulous cleanliness of all the apparatus employed, and the attention given to accurate temperature at the different stages, whilst ocular evidence will be afforded of the proportion of dirt extracted by the process of filtration from even carefully safeguarded milk.

(*L*) *Pasteurization of Milk.*

MATERIALS: *Milk; cotton wool; water.*

APPARATUS: *Test tubes; flask; c.c. measure; thermometer; water-bath; retort stand; Bunsen burner.*

(1) Place 50 c.c. of milk in a large test tube or flask. Plug the mouth loosely with cotton wool and support the vessel in a water-bath one-third full of water over a Bunsen burner. Raise the water to 100° C. (212° F.) and keep at boiling point for at least 35 minutes. Take the temperature of the milk before removing it from the water-bath; it should register 80° C. (176° F.). Instantly replace the plug of cotton wool and plunge the vessel into cold water below 10° C. (50° F.).

(2) Place 50 c.c. of milk in a test tube or flask (*a*) which has been carefully sterilized and place 50 c.c. more in a similar but unsterilized vessel (*b*). Plug the mouth of (*a*)

loosely with sterilized cotton wool, leave (*b*) uncovered, and set both aside in a cool place. Examine both specimens, and note any changes which occur in either vessel during three or four days.

NOTE.—The pasteurized milk should keep sweet and good from 50 to 70 hours longer than that which has not been so treated. The more thoroughly milk has been cooled *after* pasteurization the better it keeps.

Experiments have shown that milk which has been pasteurized at 75° C. (167° F.) for 15 minutes, or at 68° C. (154° F.) for 30 minutes, and then cooled, will keep in the hottest season for 30 hours, while if the atmospheric temperature be lower the milk will keep longer.

The United States Department of Agriculture published in its Year Book for 1894 an excellent suggestion by Dr. A. De Schweinitz for a simple, home-made apparatus designed for the domestic pasteurization of milk (*Fig*. 73).

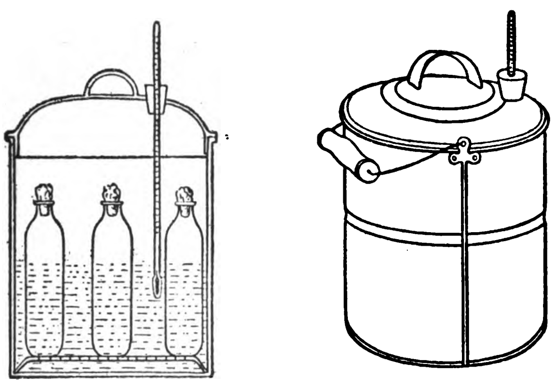


FIG. 73.*

It is described as follows:—"Take a tin pail and invert a perforated tin pie plate in the bottom, or have made for it a removable false bottom perforated with holes and having legs half an inch high, to allow circulation of the water. The milk bottle is set on this false bottom, and sufficient water is put into the pail to reach the level of the surface of the milk in the bottle. A hole may be punched in the cover

* Sterilizing Apparatus used in the Bureau of Animal Industry; reproduced by kind permission from the Year Book of the United States of America Department of Agriculture for 1894. Washington: Government Printing Office.

of the pail, a cork inserted, and a chemical thermometer put through the cork, so that the bulb dips into the water. The temperature can thus be watched without removing the cover. If preferred, an ordinary dairy thermometer may be used, and the temperature tested from time to time by removing the lid. This is very easily arranged, and is just as satisfactory as the patented apparatus sold for the same purpose."

It is important to draw attention to the fact that liquids such as water and milk which have been sterilized by heat require more careful protection subsequent to the process than before.

Many different varieties of micro-organisms exist in nature of which the greater number exercise a beneficial and protective influence rather than a detrimental or destructive one. In the course of sterilization the protective micro-organisms present in substances exposed to this treatment are destroyed equally with any germs of disease which may possibly be present, so that, should dangerous micro-organisms subsequently gain access to such sterilized fluids, the process of germ-multiplication is even more rapid than under normal conditions. It is therefore of the highest importance that vessels containing boiled milk or water should be immediately covered with some non-absorbent, perfectly clean substance, preferably glass, upon the surface of which dust, grease marks, or other impurities are easily detected. If a cloth or folds of muslin be used there is risk lest they should have been previously employed for other purposes, and the dirt absorbed by them would suffice to contaminate the fluid even though invisible to the naked eye.

(*M*) *A Test for Efficient Pasteurization of Milk.*

MATERIALS: *Milk; Allenbury's Infant's Food; aqueous solution of hydrogen peroxide; potassium iodide solution; starch solution.*

APPARATUS: *Test tubes.*

Label 3 test tubes (*a*), (*b*) and (*c*). Pour into:—

(*a*) 10 c.c. of boiled milk,

(*b*) 10 c.c. uncooked milk,

(*c*) 10 c.c. of Allenbury's Infant's Food (a preparation of dried milk).

Add to the contents of each test tube one drop of dilute aqueous solution of hydrogen peroxide, 2 drops of potassium iodide solution, and 2 drops of starch solution. Shake the contents violently after making these additions.

Does any change of colour occur immediately in any of the three solutions? Does it take place in the cooked or the uncooked milk?

NOTE.—In the year 1889, Professor Babcock of Wisconsin showed that, when hydrogen peroxide was added to raw milk, it was split up into water and free oxygen, while in milk which had been previously boiled no such reaction took place. Later investigations have proved the presence in milk of an unorganized ferment, or *enzyme*, to which this reaction is due. This enzyme is destroyed by being heated to a temperature of 80° C. (176° F.). It is found in all milk and in the products of milk, *viz.*, cream, separated milk, butter-milk, and whey, so long as these have not been heated to 80° C. (176° F.) or over; its presence can even be demonstrated in butter, provided this is made from cream which has not been heated to 80° C. (176° F.). The addition of one drop of a dilute aqueous solution of hydrogen peroxide to 5 or 6 c.c. of milk, followed by a few drops of a solution of potassium iodide and starch, will give an immediate blue colour if the milk is fresh.

(*N*) *To Detect the Presence of certain Preservatives in Milk.*

MATERIALS: *Milk; boracic acid solution; turmeric paper; hydrochloric acid; solutions of carbonate and bicarbonate of soda.*

APPARATUS: *Test tubes; c.c. measure; glass rod; beakers; water-bath; retort-stand; bunsen burner.*

(1) *Boracic Acid and Borax.*

Take two test tubes (*a*) and (*b*). Put 10 c.c. of milk in each tube, and add five drops of dilute boracic acid solution to (*a*).

Slightly acidify the contents of both test-tubes with dilute hydrochloric acid, and warm, on a sand-bath, over a bunsen flame or in a water-bath.

Immerse a strip of turmeric paper in both test-tubes; remove and dry the paper at a temperature not exceeding 100° C. (212° F.). A ruddy-brown colour will appear on the paper immersed in (*a*), which will change to green when moistened with a solution of carbonate of soda. How do these results compare with the effects of similar treatment applied to the strip immersed in (*b*)?

NOTE.—In practice, the colouration will vary according to the amount of boracic acid or borax present in the specimen of milk. Students are cautioned that ammonia gives a colour when applied to turmeric paper which is easily mistaken by inexperienced or careless persons for this boric acid test. (*See also "Preservation of Food by Chemical Means," p.* 463.)

(2) *Sodium bicarbonate.*

Place 200 c.c. of fresh milk in two beakers (*a*) and (*b*). To (*a*) add 10 c.c. of a dilute solution of bicarbonate of soda. Arrange both beakers over a Bunsen burner. Boil the contents of the beakers for one hour, adding water if necessary. It will be observed that the milk in (*a*) becomes brown, a result which invariably accompanies prolonged boiling when sodium bicarbonate has been added to milk.

NOTE.—The object for which such an addition is made is to mask the formation of lactic acid by neutralizing it with an alkali. This does not, however, serve to make such milk wholesome or to restore it to its original chemical composition.

(*P*) *Formalin, or Formaldehyde.*

MATERIALS: *Milk; 40% formalin solution; sulphuric acid (specific gravity, 1·700); ammonia or bicarbonate of soda.*

APPARATUS: *Test tubes; c.c. measure.*

Prepare four large test tubes, (*a*), (*b*), (*c*), and (*d*). Dilute 20 c.c. of milk with its own volume of distilled water, divide into two large test tubes (*a*) and (*b*), add two drops of 40% formalin to the milk in (*b*). Pour 5 c.c. of commercial sulphuric acid into (*c*) and the same amount into (*d*). (*Use great caution in handling this acid, and pour it slowly and steadily into the tubes. Should a drop be spilt, at once apply bicarbonate of soda or ammonia, or the substance will be charred or burnt.*)

Carefully float the contents of (*a*) on to the surface of (*c*) by tilting (*c*) somewhat horizontally, and pouring the milk from (*a*) very gently down the side of (*c*). Raise (*c*) gradually and steadily to a vertical position.

Repeat the procedure with (*b*) and (*d*). Stand both aside for a few minutes, and watch for any trace of violet colouration which appears at the line of junction of the two liquids in either tube.

NOTE.—This test detects the presence of 1 part formalin in 50,000 of milk.

The specific gravity of commercial sulphuric acid must be reduced from 1·840 to 1·700 for this experiment, otherwise the violet colouration, characteristic of the presence of formalin in milk, may be obscured by the purplish zone which forms when pure milk comes in contact with commercial sulphuric acid, due to charring at the line of junction. The commercial acid must be used on account of the trace of iron it contains.

In order to emphasize the importance of attention to details, direct one or two pupils to float milk over concentrated sulphuric acid and also over that in which the specific gravity has been lowered. The difference between the dark ring at the junction of the liquids in the first case and the pale, yellowish colouration in the second will serve to impress the point.

If pure sulphuric acid only is available, the addition of a trace of ferric chloride will be sufficient to meet the need for its presence. In doubtful cases allow the contact to continue at least an hour before recording the result as a negative.

There are many processes by which the presence of formalin can be detected in milk, but this method, when carefully carried through, combines the advantages of being at once delicate and easily applied.

The attention of pupils should be called to the Report of the Departmental Committee appointed to enquire into the use of preservatives and colouring matters in food. Among other recommendations the committee advise "that the use of any preservative or colouring matter whatever in milk offered for sale in the United Kingdom be constituted an offence under the 'Sale of Food and Drugs Act'"; and many local authorities are disposed to support this recommendation should it be adopted and enforced.

Stated briefly, the following are the chief causes which render milk unfit for human food:—

(1) Changes brought about by acid-forming bacteria.

(2) The presence of various fungi and moulds.

(3) The presence of pathogenic micro-organisms, *e.g.*, those of scarlet fever, diphtheria, enteric fever, cholera and, most important of all, tuberculosis.

(4) Toxic principles added either as colouring matters or as preservatives, or drugs, etc., consumed by the cow.

(5) The unhealthy condition of the cow if suffering from disease such as tubercle, cattle plague, foot-and-mouth disease, etc.

II.—The Feeding of Infants.

(*A*) *The Process of Milk Digestion.*

MATERIALS: *Milk; rennet; pepsin.*

APPARATUS: *Beakers; test tubes; pipette; glass rod; retort stand; water-bath; Bunsen burner.*

Warm 50 c.c. of milk to 36° C. (100° F.) in a beaker arranged in a water-bath over a Bunsen burner. Mix a few drops of rennet and 2 c.c. of pepsin (*p.* 186) in a test tube; drop the mixture slowly into the warm milk by means of a pipette. Stir gently with a glass rod. Carefully observe the order of the changes which will take place in the milk. Endeavour to distinguish between the two processes of "curdling" and "clotting." Note very carefully the character and consistency of the clot as it forms.

NOTE.—Milk, it must be remembered, is a fluid only outside the body; it rapidly forms a clot when received into the stomach owing to the action of the rennet ferment present in the gastric juice. Thus it undergoes profound internal alterations, rendering it practically a new substance with new characteristics.

Clotting precedes curdling in the stomach because the alkaline salts of milk first neutralize the acid secreted by the stomach, and the observations of physiologists confirm the fact observed in this experiment that, in the process of milk digestion, clotting always occurs before curdling.

One of the chief difficulties which presents itself in the artificial feeding of infants lies in the fact that cow's milk tends to form a dense, retracted clot in the human stomach, while that formed under the same conditions by human milk is loose, friable and easily broken up by the muscular movements of the stomach in conjunction with the digestive juices. This density of the clot in cow's milk is the chief cause of its indigestibility at any period of human life, but more especially in the case of infants. The richer the milk in casein and soluble salts of lime, and the more acid the gastric juice in the stomach of the consumer the tougher is the clot formed.

It must also be borne in mind that proteids are represented in milk by both casein and albumin, of which the proportions in cow's milk is 6 of the former to one of the latter, whereas in human milk they are present in about equal proportions. Now as albumin is much the more easily digested of the two forms of proteid, it is evident that this difference of proportion constitutes an important practical difference between the two types of milk, affecting as it does the character and consistency of the clot formed in the stomach.

It has been also suggested that the greater density of the clot may be in part due to the smaller proportion of fat in cows' milk, for the soluble albumin and characteristic fat of human milk seem to exercise some mechanical influence in producing the loose clot. Boiled milk is found to clot more slowly outside the body and to give a less dense clot than raw milk, but the best authorities on the subject consider it unwise to assume that boiled milk behaves similarly in the stomach.

Dr. McCleary has pointed out in Chapter III. of his book on "Infantile Mortality" (P. S. King & Son) that:—

"This subject is so important that it may be considered in fuller detail. Dr. Chaplin has called attention to the significance of the comparative anatomy of the digestive tract in relation to infant dietetics. He points out that in each species the 'milk of the mother behaves in the young animals' stomach very much as the food of the mother behaves in her stomach. The young animal is being educated to digest in the same manner as it will when it is grown.' In the cow, goat and sheep there are four stomachs, which together form about 70% of the digestive tract, and the outlet between the fourth stomach and the intestine is

small, admitting of the passage of only liquid or semi-liquid food. On the other hand in the horse and ass, which eat the same kind of food as the cow, there is but one stomach, which forms only eight or nine per cent. of the digestive tract and holds not more than one half of a meal. The outlet to the intestine is large, and at the other end of the intestine is an enormous cæcum, which forms about 60 per cent. of the entire digestive tract. These differences in structure suggest differences in the process of digestion. Although these animals eat the same food, it is evident that, in the former, digestion must take place chiefly in the stomach, and in the latter, chiefly in the intestine, and this is what actually happens. Now, the milk of each species is suited to the structural character of the digestive apparatus. The milk of the cow clots with a firm, hard curd, which must be digested before it can pass from the stomach to the intestine; the milk of the horse on the contrary, forms a jelly-like clot which passes readily into the intestine, where it is digested. Thus from the same food these animals produce milks of widely different properties. The human stomach forms about 20 per cent. of the digestive tract and the outlet to the intestine is small. It would appear, therefore, that this stomach is adapted for the reception of finely divided material which can be passed easily into the intestine, where the main part of digestion occurs. The indigestion which follows defective mastication confirms this conclusion, and so does the behaviour of human milk, which, in clotting, forms not a solid lump, nor a fluid jelly, but a soft finely divided mass. . . . The making of milk is not a mere filtration from the blood, but a biological process depending on the vital activity of the milk-secreting cells of the breast; and the more the comparative chemistry of milk is studied, the more clearly does it appear that the milk of each species is specialized to meet the needs of the animal. . . .

"Recent research has led to the discovery of profound physiological differences between the milks of various species. Milk is not an inert liquid depending for its nutritive properties on the chemical substances it contains; it is a living liquid with important biological properties. Milk contains soluble ferments which no doubt play an important part in the nutrition of the infant. It has long been known that the processes of digestion are chiefly carried on by ferments elaborated in the digestive tract and its appendages, and there is now good reason to think that the processes of assim-

ilation depend largely upon the presence of ferments elaborated in internal secretions. Zweifel, Czerny and other observers have found that the infant's blood and digestive juices are relatively poor in ferments, and according to the hypothesis of Escherich and Marsan it is an important function of mother's milk not only to supply a food suited mechanically and chemically to the infant's feeble digestive capacity, but also to furnish ferments which stimulate and regulate the nutrition of the infant's tissues. It is true that cows' milk also contains ferments, but they differ from those in human milk. For instance the latter contains an amylolytic ferment which is absent from the milk of the cow."

Dr. Hutchison has also drawn attention to the different percentage proportion of constituents in human milk and cow's milk as they affect the immediate necessities of a child's body. According to reliable analysis, the average proportion of the constituents of the milk of different species of animal is as follows:—

	Proteid.	Fat.	Milk sugar.	Ash.
MAN	1·6	3·4	6·1	0·2
COW	3·5	3·7	4·9	0·7
ASS...	2·2	1·6	6·0	0·5
CAT...	7·0	4·8	4·8	1·0

It will be observed that there is a close correspondence between the proportion of the proteids and salts in these milks and the rate of growth of the young animal.

An infant requires, relatively, more body-building constituents (proteids and salts) than the adult, and less energy producing substances (carbohydrates) (*Fig.* 61). Fats are, however, of great importance; any deficiency rapidly resulting in disorders of nutrition. Mineral ingredients (represented by the "ash") are as essential as proteids to sturdy growth, and these are represented by salts of lime, potash and phosphoric acid, in all of which human milk is particularly rich, while they are present in the form most adapted to absorption by the infant.

Variations in the quality of the milk occur also throughout the period of suckling. The tissue-forming elements tend gradually to diminish in quantity after the first weeks of very rapid growth (when an increase in weight takes place of from

35 to 40 grams ($1\frac{1}{2}$ to $1\frac{3}{4}$ ozs.) daily). By the sixth month this has diminished to a daily addition of 18 grams (about $\frac{1}{8}$ of an ounce) to the weight, but meanwhile the proportion of carbohydrates increases, to meet the needs of the child's increasing muscular activity. The infant's natural food therefore does not become richer as the body gets older, but increases in quantity and varies in quality as more nutriment becomes necessary.

(*B*) *Methods Employed to Influence the Character of the Clot, formed by Cows' Milk.*

MATERIALS: *Milk; rennet; pepsin; lime-water; barley-water;* 25 % *solution of citrate of soda.*

APPARATUS: *Small vessels; thermometer; large pan; retort stand; Bunsen burner.*

Take five small vessels (*a*), (*b*), (*c*), (*d*), (*e*). Place in:—

(*a*) 30 c.c. milk at 38° C. (100° F.), plus 6 drops of the rennet and pepsin mixture used in (*A*).

(*b*) 30 c.c. *boiled* milk at 38° C. (100° F.), plus 6 drops of the same mixture.

(*c*) 30 c.c. *unboiled* milk at 38° C. (100° F.), plus 6 drops of the mixture and 15 c.c. lime-water.

(*d*) 30 c.c. *unboiled* milk at 38° C. (100° F.), plus 6 drops of the mixture and 15 c.c. barley-water.

(*e*) 30 c.c. *unboiled* milk at 38° C. (100° F.), plus 1 c.c. of 25 % solution of citrate of soda and 6 drops of the mixture.

Stand all the vessels in warm water and maintain a temperature of 38° C. (100 F.) for one hour.

Compare the results in each case, and note the relative effects of these agents in delaying rennet coagulation.

NOTE.—On comparison, the difference in the clots formed in the various vessels will be quite evident. There will be a tough clot in (*a*) and (*b*), for boiling does not alter the character of the clot. A clot of looser character will be formed in (*c*) than in (*d*), while in (*e*) there will be a decidedly finer and more friable clot, the fluid being more translucent than in any of the other vessels.

The addition of barley-water to cow's milk is designed to prevent the formation of the dense, tough clot seen in (*a*) and (*b*), but Dr. Hutchison finds that it possesses no greater power to prevent clotting than does ordinary water, though by its slight degree of viscidity it hinders the clot from subsequently shrinking into a tough mass. Most people overlook the fact that barley-water contains starch, a nutritive principle undesirable in any form for young babies. Indeed, in the opinion of some experts on infant feeding, barley-water is not considered admissible on this account, and in any case the same effect is gained with less trouble by the addition of a little corn-flour or gruel.

Dilution with lime-water is more efficacious to prevent the formation of a dense clot, one part of lime-water to two of milk being sufficient, probably by virtue of its alkalinity which postpones rennet coagulation. The proportion of lime thus added converts the salts already present into a less soluble form.

Explanation of the less dense clot in (*c*) is found in the fact that it was ascertained some years ago by Arthus and Pagès that cow's milk did not clot with rennet, when the lime salts present had been precipitated by a suitable reagent; and the principle was applied by Sir A. E. Wright to infant feeding. He pointed out that the milk dyspepsia of babies is chiefly the result of the indigestibility of the rennet curd, formed when milk is taken on an empty stomach. If some of the lime salts in cow's milk are precipitated the clot formed by the rennet ferment is delayed in time, is less firm in its consistence, and is thus more digestible. Cow's milk can well afford this precipitation of some of its lime salts, as they are present greatly in excess of an infant's requirements.

It has been found in practice that the addition of 6·5 centigrams (1 grain) of citrate of soda to each 28 c.c. (1 oz.) of milk results in the formation of the desired loose, friable clot by bringing about the precipitation of salts, and the taste of the milk is not affected materially by this proportion (1 in 200) of added citrate of soda. This is a cheap article (about 2*d*. per oz.), and also a neutral salt, so that it does not tend to interfere with the normal secretion of the gastric juice; nevertheless, it should only be employed under medical direction.

(*C*) *The Artificial Feeding of Infants.*

MATERIALS: *Milk; cream; lime-water; sugar mixture; specimens of patent foods; iodine; Fehling's solution; benzine; 1 % solution of osmic acid; water.*

APPARATUS: *Jug or bottle; slip of glass; large vessel; test tubes; thermometer; retort stand; Bunsen burner.*

(1) *A Method of Preparing Cow's Milk for Infants' Diet.* (Dr. Eric Pritchard.)

Take of Cream	... ...	2 parts.
Milk	... ...	1 part.
Lime-water	...	1 ,,
Sugar Mixture	...	10 parts.

Mix all thoroughly in a carefully sterilized jug or bottle, cover with glass, and stand aside in a large vessel of cold water, in a clean, cool place.

NOTE.—This method of modifying milk is inserted in order to emphasize the great difficulty, care and trouble of adapting cow's milk to the requirements of a young baby.

The proportion of proteid, sugar and fat in this mixture is approximately correct, but the casein remains relatively higher and the albumin relatively lower than in human milk; neither is the mixture a sterile fluid, nor can it be ensured that it will be consumed invariably at body heat—the temperature suited to the delicate mucous membrane of the child's mouth and stomach.

To prepare the sugar mixture, dissolve 50 grams (1¾ ozs.) of milk-sugar in 500 c.c. (1 pint) boiled water; it will not be fit for use if kept for more than twenty hours.

It will be remembered that the carbohydrate constituent of milk is *lactose* or milk-sugar, which differs very much from cane sugar and in nothing more than its diminished sweetness, a valuable property in a substance employed as a food and not as a condiment. It is true that lactose is very liable to lactic acid fermentation, but on the other hand starch, cane sugar, dextrine, and dextrose all feed the butyric ferment, which sets up digestive disturbances.

Cream which has been "separated" from milk is much more concentrated than that skimmed from the surface of milk by old-fashioned dairy methods. It should be therefore diluted with one part of water if used for an infant's diet.

Suggest the value of cod-liver oil to supply the deficiency of fat in the diet of an artificially fed baby where the cost of cream is prohibitive; the oil is well taken by an infant in small quantities, *i.e.*, about 30 or 40 drops twice or thrice a day immediately after a feed.

Many formulæ are published for the modification of cow's milk, but with older pupils stress may well be laid upon the extreme difficulty of preserving the right proportions of nutrient principles where dilution with water, barley-water, lime-water, etc., must be resorted to.

Dr. James Knight, of Glasgow, when writing on "The Chemistry of Infants' Foods" has worked out the following figures in connection with dilution:—

"In giving 500 grams of milk and water (1 : 1) we are giving only 7·03 grams of proteids, 8·05 of fat, 13·04 of sugar, and 1·50 of salts. Taking the total solids of human milk at 123 grams per litre and of cow's at 135 grams, then by using milk and water (1 : 2) we have only $\frac{135}{3}$, or 45, of total solids, or only 22·5 grams in 500 grams of milk, the daily supply. But 500 grams of human milk contain $\frac{123}{2}$, or 61·5, *nearly three times as much*, a fact quite sufficient to account for retarded growth. Morfan has now reduced his dilution to 2 of milk to 1 of water, which still gives 45 grams of total solids compared with 61·5 for human milk. Dr. Variot, who has been obtaining wonderful results with sterilized milk, dilutes this with only one-third of water till the eighth week of life, by which time the stomach capacity of an infant has trebled, from 30 grams to 90."

Physicians have repeatedly drawn attention to the fact that, when artificially fed, infants are exposed to the following among many other risks:—(1) semi-starvation, from over dilution of their food; (2) dyspepsia caused by wrongly proportioned food, chiefly a deficiency of fat and an excess of carbohydrates; (3) the presence of constituents in unnatural forms shown by the formation of dense, tough clots; (4) the development of lactic acid; (5) milk infected by tuberculosis and other disease germs.

Allusion should be made to the *Roussel* Law in France, which prohibits the administration of solid food to children under a year old without the express permission of a doctor. This has had the effect of largely diminishing the sale of patent foods, but has not yet entirely banished the delusion that infants benefit from the addition of starch preparations to their food.

(2) *Test some samples of Patent Foods for the presence of:—*

(*a*) Unaltered starch.
(*b*) Grape sugar.
(*c*) Fat.

Mix a small quantity of each specimen of patent food to a paste with water, then add sufficient water to liquefy it. Transfer to a large test tube or flask and boil for two or three minutes. Remove from the source of heat and cool to 38° C. (100° F.).

Prepare three test tubes (*a*), (*b*) and (*c*), and pour a portion of the prepared foods into each tube.

Test the contents of (*a*) with iodine, of (*b*) with Fehling's solution, and of (*c*) with benzine or 1% solution of osmic acid. Describe the first specimen as I., the second as II., the third as III., and so on.

Tabulate the conclusions you form as to the presence and apparent amount in each specimen of starch, dextrose and fat. For example:—

	Starch		*Dextrose*		*Fat*
I.	A little	...	Much	...	None
II.	Much	...	A trace	...	A trace
III.	Much	...	None	...	A little

NOTE.—It is advantageous to subject specimens of the patent foods on the market to tests for the presence of starch, sugar and fat in order to show how materially the majority differ in their composition from the requirements of an infant's diet. The even wider divergence which is allowed should be noted, for the vague directions attached to most of these "foods" permit water or milk to be used indifferently, and often leave quite undefined the quantity of the preparation to be used for a meal at different age periods.

Iodine will prove the presence of unaltered starch in several of the most widely advertised foods; a complete deficiency of fat and an excess of grape sugar will also be revealed. The analysis of the constituents of the following Infants' Foods is that adopted by Dr. Hutchison in "*Food and the Principles of Dietetics*" (*Edward Arnold*), where he writes:—"No proprietary food in the market possesses any real advantage over the best brands of condensed milk, and

they should all be avoided as complete foods for infants if fresh milk is obtainable. If used as additions to a diet of milk, those only should be employed, before a child has cut its teeth, in which the starch is entirely converted into soluble forms. The patent foods in which the starch is unconverted, possess no advantages as additions to the diet of older children over such simple articles as oat flour, rusks and rice, and are considerably more expensive."

COMPOSITION OF INFANT FOODS.

Food.	Water.	Proteid.	Fat.	Carbo-hydrate	Mineral Matter.
DRIED HUMAN MILK	—	12·2	26·4	52·4	2·1
Allenbury No. 1 (for children below three months)	5·7	9·7	20·0	60·85	3·75
Allenbury No. 2 (for children of from three to six months	3·9	9·2	15·0	75·2	3·50
Horlick's Malted Milk	3·7	13·8	9·0	70·8	2·70
Nestlé's Milk Food (Knight)	5·62	10·46	4·38	77·74	1·80
Mellin's Food	6·3	7·9	trace	82·0	3·8
Savory & Moore's Food	4·5	10·3	1·4	83·2	0·6
Benger's Food	8·3	10·2	1·2	79·5	0·8
Allenbury Malted Food	6·5	9·2	1·0	82·8	0·5
Ridge's Food	7·9	9·2	1·0	81·2	0·7
Neave's Food	6·5	10·5	1·0	80·4	1·6
Frame Food Diet	5·0	13·4	1·2	79·4	1·0
Robinson's Groats	10·4	11·3	1·6	75·0	1·7
Robinson's Patent Barley	10·1	5·1	0·9	82·0	1·9

The chief defect of most brands of condensed milk, from the point of view of the infant, lies in the fact that they contain in most instances too little fat and a great excess of cane sugar, thus they form a fertile source of malnutrition. Excessive fatness gained at the expense of firm flesh is no indication of health. Unsweetened, condensed milks are more satisfactory, but are liable to decompose very quickly when the tins are opened, in all cases condensed milks are costly, the price per pint working out at double that of fresh cow's milk.

(D) The Care of Feeding Bottles.

Materials: *Milk; carbonate of soda.*

Apparatus: *Fine rubber tubing; 2 rubber nozzles; c.c. measure; beaker; retort stand; Bunsen burner.*

(1) Take two short lengths of fine rubber tubing (*a*) and (*b*). Pass quite slowly through (*a*) about 100 c.c. of milk at 38° C. (100° F.). Repeat this at intervals of a few hours for several days. Between each treatment keep the tubes in a warm place.

After a week, slit (*a*) open and observe its condition, odour and appearance. Compare these with (*b*). What deduction is to be drawn as to the propriety of using such tubes for purposes of infant feeding?

(2) Take two rubber nozzles (*a*) and (*b*) such as are attached to infants' feeding bottles. Immerse both in warm milk for a quarter of an hour; then cleanse (*a*) thoroughly in a solution of carbonate of soda and water, and when clean place it in fresh cold water. Remove (*b*) from the milk, wipe the exterior and lay it aside. Repeat this procedure with both (*a*) and (*b*) on several occasions during consecutive days and compare the results. (Repeat I. (*H*), *page* 389.)

XVIII.—BEVERAGES AND THEIR CHARACTERISTICS.

Water. Aerated waters. Acidulated drinks. Nutrient drinks. Alkaloidal beverages. Alcoholic beverages.

I.—Water.

MATERIALS: *Distilled water; tap water; rain water; pond or river water; sheet of newspaper and white paper; cloth; neutral litmus paper; taper.*

APPARATUS: *Tall, glass gas jars; thermometer; glass flasks with glass stoppers; bowl; conical glass vessels or test tubes; porcelain basins; pipette; Petrie dishes; sand-bath; retort stand; Bunsen burner.*

(*A*) *Properties of Water.*

Take four tall, clear glass jars, about 60 cms. (2 feet) high, (*a*), (*b*), (*c*) and (*d*). Stand them side by side upon a sheet of clearly printed newspaper. Fill:—

(*a*) with distilled water;

(*b*) with tap water;

(*c*) with rain water from a cistern, the roof or a water-butt;

(*d*) with water from a puddle, ditch, pond or river.

Arrange a sheet of white paper to form a background to the jars. Test the temperature of the water in each jar; it should register 15° C. (59° F.). If necessary, therefore, slightly warm or chill whichever sample varies from this standard. (A rapid method of lowering the temperature of water is to surround the vessel with a wet cloth. *See* "WATER," III. (*C*) (3), *page* 64.)

Each sample of water should be allowed to stand for a sufficient length of time before use, in order to allow any suspended matters present to be deposited as sediment. The supernatant water must then be poured into the jars. Observe to what extent (*b*) and (*c*) possess the following characteristics, all of which are obviously present in (*a*).

(1) *Appearance.* Are the samples so clear that the print can be read in each case on looking straight down through the column of water to the newspaper upon which the jars are stood?

(2) *Colour.* Is the water colourless in each jar? A slight blue or grey colouration may be present in wholesome water; *brown* or *yellow* should arouse suspicion on the score of purity.

(3) *Reaction to neutral litmus paper.* Restore to the respective sample in each jar any sediment deposited in the different types of water from which the jars were filled, then test the reaction of each sample to neutral litmus paper.

NOTE.—The reaction of water is usually slightly acid, but if the source of the water is a soil rich in alkaline carbonates the reaction may be faintly alkaline. The reaction of the best potable water is neutral.

(4) *Taste.* Withdraw a drop or two of water from each jar in turn to taste its flavour, using a clean pipette for each specimen.

Good water is palatable but practically ***tasteless***. Any "taste" should arouse suspicion as to purity, and such water should be discarded from use for drinking or cooking purposes, unless subjected to prolonged boiling.

(5) *Smell.* Pure water has *no smell*, but an odour may develop in water after standing for some time which was free from any smell when freshly drawn. To make this test, therefore, proceed as follows:—

Take four glass flasks (i.), (ii.), (iii.) and (iv.) fitted with glass stoppers or with rubber corks previously well boiled. Half fill—

(i.) with water from (*a*);
(ii.) with water from (*b*);
(iii.) with water from (*c*);
(iv.) with water from (*d*).

Stand the four flasks in a bowl of water at a temperature of 40° C. (104° F.) for some minutes; then remove each stopper or cork in turn and take a deep sniff from each flask.

NOTE.—By this test, smells imperceptible while the water is cold will often become apparent or even intense and reveal unsuspected impurities.

(6) *Suspended and sedimentary matters.* Thoroughly shake the water in each cylinder and pour off a few c.c.'s into four conical glass vessels or large test tubes (*a*), (*b*), (*c*) and (*d*). Allow sufficient time for turbidity to subside.

Meanwhile, label four small porcelain basins (*a*), (*b*), (*c*) and (*d*), then withdraw about 50 c.c. from the bottom of each specimen by means of a long straight pipette and transfer to the basin lettered to correspond. Slowly evaporate the water on a sand-bath over a small Bunsen flame. Touch the residue when dry with a lighted taper. If it turns black the presence of organic matter is indicated.

7. Prepare four sterilized Petrie dishes (i.), (ii.), (iii.) and (iv.), repeat "SOME CHARACTERISTICS OF WATER," (*F*) (2), *p.* **66**. Set aside for eight days under the conditions

directed, and then endeavour to count the slimy spots, if any, which are found on the surface of the gelatine, each of which represents a colony of bacteria.

If (*c*) be drawn from a very foul source, it is possible that an earlier counting will be necessary, as liquefying bacteria will be most probably present and will quickly destroy the surface of the gelatine by their liquefying action. (*See Note, page* 55.)

NOTE.—It is difficult to draw a sharp line of demarcation between water which is or is not wholesome for drinking or for domestic purposes, though naturally all water should be *free* from matter which in itself is dangerous to health. Nothing less than repeated and scientifically accurate examination of water samples can be accepted as reliable evidence on the point, for normal waters vary very considerably in general characters, composition and appearance. It is the work of an expert to determine whether a water may or may not be safely used as a beverage, but care should be taken to open the eyes of students to the chief sources of unwholesome water, and to direct their attention to the need for vigilance in the protection of water supplies either domestic or public.

The extent to which printed matter is obscured when read through water under the conditions defined in (*A*) is accepted as a fair test of *turbidity*, which is usually caused by the presence of organic and mineral matters in suspension. Some waters which are clear when first drawn become turbid on standing, owing to some change in composition and to precipitation of iron compounds, such turbidity is accompanied by a slight colouration which usually disappears when the mineral compound separates as a sediment.

A *brownish* or *yellow* colour may be due to iron or to peat; more frequently it is significant of sewage contamination. A green tinge is generally caused by harmless algae. Absence of colour is no reliable sign of purity, while its presence is by no means an invariable reason for condemning water as unwholesome.

The taste of good water is agreeable, owing to the presence of contained gases. Vegetable impurities may occasionally render water bitter and unpleasant, but animal organic impurities are usually the cause of unpleasant flavours.

When testing for smell, care must be taken that the sample has been kept carefully covered, and the person who makes the test should come if possible almost directly from the fresh outside air. Unpleasant odours may be caused by processes of chemical or putrefactive decomposition, by the growth of vegetable substances, or by the physical disintegration of organic matter. They are not always indicative of unwholesome conditions in water, which are constantly present in the absence of any smell, but they usually suffice to condemn a water for potable purposes.

Only gross impurities can be seen by the naked eye in the sediment deposited by water; in *all* cases microscopical as well as bacteriological examination is necessary to identify the constituents of such sediment, in which hair, skin and other evidence of foul organic pollution are usually found. Moulds, yeast and bacteria, derived chiefly from the soil and air, are present in most waters. The greater number of water bacteria are fortunately harmless and many are beneficent, for they convert contaminated, dead, organic matter into simpler chemical substances. About 200 such varieties have been identified and described, therefore the microbes found in water are classified as non-pathogenic and pathogenic. Among the first group it is well to refer to the *Bacilli coli communis*, whose presence in any number strongly suggests sewage contamination. The bacilli of enteric fever and cholera are the most important pathogenic micro-organisms, though others are believed to find their habitat occasionally in water, for instance, those of anthrax, malaria and dysentery.

Prolonged boiling should be once more emphasized as the one reliable means possessed by the individual to safeguard his consumption of any water concerning the purity of which the least suspicion could exist (*see page* 73); such water can be re-aerated with "Sparklets" or flavoured with toast, lemon, apple, &c., to restore the palatability lost by prolonged boiling. (*See also page* 370.)

There does not seem much ground for the popular belief that hard water produces stone or goître, or that rickets result from drinking very soft water. Dr. Hutchison writes that "when one remembers that even a hard water only contains about ·002 grams of lime in every 100 c.c. and that an infant requires about 0·32 grams of lime daily, it will be evident that as a source of calcium for the bones water may be practically disregarded."

II.—Aerated Waters.

MATERIALS: *Soda water; tap water; lime-water; bread crumbs; minced meat.*

APPARATUS: *Flask; glass tube; beakers; rubber cork; slips of glass; sand-bath; retort stand; Bunsen burner.*

(*A*) Fill a flask three parts full with soda water. Heat it gently over a Bunsen flame and observe the increased briskness of the effervescence.

(*B*) Quickly close the mouth of the flask with a rubber cork, through which passes a glass tube bent twice at right angles. Connect the free end of the tube with a small beaker half full of lime-water. Continue to heat the flask until the appearance of the lime-water affords a clue to the character of the gas given off from the aerated water. (V.—"AIR," IV. (*b*), *page* 54.)

(*C*) Prepare two beakers (*a*) and (*b*); half fill (*a*) with soda-water and (*b*) with tap water.

Stir an equal quantity of bread crumbs and minced meat into each beaker, cover with a slip of glass and place them on a hot sand-bath. Compare the behaviour of the mixture in (*a*) with that in (*b*). The temperature of the water should be raised to and kept at that of the body, about 38° C. (100° F.).

Keep both beakers under observation for an hour, and watch the results in (*a*) of the gradual passing off of the gas which keeps the contents in constant circulation. Compare these with the inert condition of the contents of (*b*).

NOTE.—In the one case the bread floats on the surface, remains broken up into particles and is in constant motion owing to the "bubbling up" through it of the gas contained in the water. In (*b*) the mixture sinks rapidly and collects in a more or less coherent mass at the bottom of the beaker.

The aerated waters annually consumed to the extent of about 200,000 gallons in the United Kingdom, are chiefly of artificial production. Carbonic acid gas is generated in large quantities from the action of vitriol on chalk. Ordinary water is charged with the gas at so high a pressure that the usual proportion of gas to water is at least 4 volumes to 1.

This high pressure accounts for the loss of contents so apt to occur when a bottle of aerated water is opened, the violent ebullition being caused by the release of the compressed gas. As this gas passes off in large quantities from the water it withdraws a considerable amount of heat, which explains the cooler taste of aerated water, even when stored under similar conditions and drunk at the same temperature as other water used for drinking purposes.

Very frequently no chemical salts are added to ordinary aerated waters, but in some cases from 3 to 15 grains of bicarbonate of soda or potash, or similar quantities of carbonate of lithia, are added to each bottle, which is described accordingly as soda, potash or lithia water.

The pleasant, sharp taste of aerated water is not the only dietetic advantage it possesses. There seems reliable evidence that the carbonic acid gas actually assists the process of chemical digestion by stimulating the secretion of the gastric juice, while it exercises a two-fold influence upon the mechanical process of digestion, (1) by stimulating the muscular movements of the stomach, (2) by facilitating the disintegration of the food while undergoing gastric digestion. The alkalinity of natural or artificial aerated mineral waters is also valuable as a corrective of the inhibitory action exercised upon the ptyalin of the saliva by acid wines.

III.—**Acidulated Drinks.**

MATERIALS: *Lemonade; ginger beer; lemon; powdered chalk; vinegar; solution of methyl violet; Fehling's solution; lime-water; patent preparations for making lemonade or lemon squash; ginger beer; filter paper.*

APPARATUS: *c.c. measure; test tubes; funnel; beakers; glass rod; flat, glazed, white tile or thick, glazed, white paper; retort stand; sand-bath; Bunsen burner.*

(*A*) *Test for the presence of Sugar.*

Take 20 c.c. each of lemonade and ginger beer and test for the presence of sugar with Fehling's solution, as directed on *page* 174.

(*B*) *Test for free Citric Acid in Lemonade.*

Label two large test tubes or small flasks (*a*) and (*b*). Squeeze half the juice of a lemon into a c.c. measure and

saturate it with powdered chalk, or add an equal quantity of saturated lime-water. Mix thoroughly and filter; half fill (*a*) with the filtrate.

Make a strong solution of one of the patent preparations sold for the purpose of making lemonade or lemon squash, and combine it as directed above with chalk or lime-water; filter and half fill (*b*) with the filtrate.

Arrange both vessels on a sand-bath over a Bunsen flame and boil the contents. The precipitate which forms in (*a*) is calcium citrate, and proves the presence of free citric acid in lemonade. How does it compare in appearance and quantity with that which forms in (*b*)? To test whether the precipitate in (*b*) is formed by the combination of citric acid with lime, or by tartaric or sulphuric acids (substitutes frequently employed for the juice of fresh lemons where expense is an object), set both vessels aside to cool, then test the point by the following rule. If the precipitate redissolve on cooling it consists of calcium citrate, but if the precipitate formed by heating the mixture remains unaffected, no citric acid was present in the fluid from which it was prepared. If it partially redissolve on cooling, a certain proportion of citric acid is contained in the preparation subjected to the test.

NOTE.—A bottle of flavoured and sweetened acidulated water usually contains 28 grams (1 oz.) of sugar; such beverages, therefore, possess a certain nutritive value, for 28 grams of sugar (about 6 or 8 ordinary lumps) yield over 100 calories of energy, which partially explains their refreshing influence.

The presence of so much sugar may interfere with the stomach secretions (acid) and favour fermentation, especially when the sugar is associated with mineral and not with vegetable acid.

Mineral acids are quite generally employed instead of citric acid in the making of these beverages, though acetic acid is also commonly used for the purpose, either pure or associated with mineral acids. The acidity of a bottle of this class of drink, may be calculated as the equivalent of 14 or 15 c.c. (½ oz.) of vinegar. Oil of lemon or tincture of ginger contribute the necessary flavour to these preparations.

Fermented ginger beer (stone-ginger) usually conforms genuinely to its designation. At least 2% of alcohol is always present in stone ginger beer, as a product of fermentation.

The most important point to impress in connection with the more or less fictitious preparations known as lemonade and ginger beer is the contrary effect upon the human body of vegetable and mineral acids, which is explained as follows:—

The juices of fruits and vegetables are compounds of potash with organic acids, such as tartaric (grapes), citric (lemons), malic (apples). These acids are composed of carbon, oxygen and hydrogen in combinations which are decomposed in the body (but in the body only), at 37° C. (99° F.). The excess of carbon dioxide and water which results from this decomposition is expired or ejected from the body, leaving the potash free to combine with the partially digested food in the stomach and to assist in maintaining its alkalinity. If, on the contrary, potash be combined with sulphuric, nitric or hydrochloric acids, that is, with mineral acids, no such decomposition can be effected in the body. In the one case therefore, a tendency to acid dyspepsia troubles is corrected, as all vegetable acids beget alkalies when taken into and decomposed in the stomach, whereas in the other it is accentuated, because the existing acidity is increased by the consumption of a mineral acid, which cannot thus beget an alkali.

(C) To test for presence of free Mineral Acid in Acetic Acid.

Prepare strong solutions of vinegar and of two or three specimens of artificial lemonades and ginger beers. Place two drops of each specimen and a few drops of a watery solution of methyl violet upon a flat, glazed, white tile or upon a piece of thick, glazed, white paper; keep the fluids well apart. With a glass rod bring a portion of the methyl violet into contact with the vinegar and with each sample of lemonade or ginger beer.

If there is no mineral acid present the colour remains unchanged after mixing. If a trace be present the methyl violet becomes blue. If over 1% of mineral acid is present the violet develops a green colour.

IV.—Nutrient Drinks.

MATERIALS: *Fresh, lean beef; greased paper; tape or string; butter muslin; water.*

APPARATUS: *Jar; pan; strong bowl; thermometer; knife; spoon; fork; retort stand; Bunsen burner.*

(*A*) *Milk.* (Refer to XV.—"TEST FOR PRESENCE OF PROXIMATE PRINCIPLES IN MILK," *pp.* 315-322; also to XVII.—"A STUDY OF MILK," *pp.* 380—398.)

(*B*) *Beef Tea* (after Dr. Hutchison).

Take 250 grams (½ lb.) of fresh, lean beef, trim away any gristle or fat which can be seen, then *scrape* the meat down thoroughly with the back of a knife, so that it is torn into shreds.

Place the fragments in a jar, add 250 c.c. (½ pint), of cold water and stand aside for half-an-hour in a cool place. Cover the jar tightly with greased paper, kept firmly in place with tape or string; place it in a pan of cold water and gradually raise the temperature of the water to 55° C. (130° F.). Keep at this heat for at least an hour. Stir the mixture from time to time, pressing the lumps of meat against the side of the jar with a fork. Then bring the beef tea quickly to boiling point and remove it immediately from the source of heat.

Pour off the liquid and turn the residue of the beef on to a strainer, made by stretching butter muslin firmly across a strong bowl. Squeeze the meat well with a spoon and add the expressed juice to the tea; this should then be set aside to cool, and when quite cold the solidified fat can be removed from the surface with a heated spoon. Grate down the residue of the meat into fine particles and add these to the beef tea.

NOTE.—The nutritive value of beef tea depends entirely on its preparation; it can only rank as a food when some at least of the proteid present in the meat is extracted as well as the salts and extractives, which in most cases are the only portions of the meat dissolved in the cooking process. If the beef tea

be boiled at an early stage the proteids are coagulated and become insoluble. It is the *fibres of the meat* therefore which contain the nourishment; these must be first shredded and separated from the connective tissue before the process of solution in cold water begins. It is doubtful whether the common habit of adding salt to "shed the juices" has substantial foundation. During the subsequent cooking, the temperature must be kept below the point at which albumin coagulates; the momentary boiling advised in the above recipe is only permissible when all soluble proteids are dissolved out; it has for its object to remove the raw taste and the objectionable red colour.

The tea must be poured (not strained) off the meat residue, otherwise the lower layer of flocculent particles, visible after cooling, would have been kept back and it is they which constitute the nutritive part of the beverage. The upper or fluid layer is merely a solution of salts and extractives, which correspond to the whole tea when it is ignorantly prepared.

As coagulation of the proteids is only permitted at the final state of the cooking process it results in the formation of very fine light particles, easy of digestion by reason of the large surface they expose to the gastric juice.

The cost of 700 c.c. (1¼ pints) of such beef tea will be about one shilling; it contains about 1·5 or 1·75 of proteid and a similar amount of salts and extractives. It is calculated that 4½ litres (9 pints) would be necessary to meet the daily proteid requirements of an invalid! Evidently therefore, beef tea possesses little actual nutritive value; but it often promotes appetite and undoubtedly it exerts a refreshing influence upon persons when tired, weak or cold. (*See* "*The Effects of Cooking upon Meat,*" *A* (3), *page* 357.)

The only means of getting the full power of meat in small bulk is by the use of Meat Powders, which are however, very costly.

According to the best authorities, the nutritive value of barley-water or toast-water is practically *nil.*

No reference is here made to cocoa as a nutritive drink, for though the chemical analyses of its composition suggest that it possesses a somewhat high nutritive value (*see p.* 423), practically this does not amount to much unless the beverage be made entirely with whole milk and sugar; even then not more than 10 grams (⅓ oz.) of cocoa can be taken at one time

(*i.e.*, three breakfast cups full prepared according to the printed directions issued with the various preparations of cocoa on the market), a quite insignificant contribution towards daily requirements. For instance, thirty grams (1 oz.) of cocoa only yields 120 calories of heat, while the daily requirement for an adult is at least 2,000. It is obviously impossible, therefore, to look to cocoa seriously as a source of nutrition unless consumed in inconveniently large quantities, but it affords a welcome variety in flavour to those who consume considerable quantities of milk, more especially for children or for those who, while desiring a hot beverage, do not wish to drink tea or coffee.

V.—Alkaloidal Beverages.

MATERIALS: *Tea; freshly ground coffee; cocoa powder; egg albumin solution; gelatine solution; bicarbonate of soda; cotton wool or flannel; perchloride of iron solution; solution of tannin; ether or benzine; iodine.*

APPARATUS: *Gas-jars; beakers; slips of glass; test tubes; pipette; small porcelain evaporating dish; thermometer; air-oven; water or sand-bath; retort stand; Bunsen burner.*

(*A*) *Tea.*

(1) Pour 200 c.c. of boiling water over 6 grams of tea, previously placed in a gas-jar or beaker, and cover the jar with a slip of glass. Surround it with cotton wool or flannel to maintain the tea infusion at a high temperature.

Prepare four test tubes (*a*), (*b*), (*c*) and (*d*). After the tea has infused 5 minutes remove 15 or 20 c.c. of the beverage with a pipette and transfer it to (*a*), then add 3 or 4 c.c. of a dilute solution of perchloride of iron.

Repeat the process of thus transferring the tea infusion to (*b*), (*c*) and (*d*) successively, at intervals of 5 minutes. Then compare the colouration of the tea in the four tubes at the conclusion of the experiment. A blue or bluish black colour indicates the presence of tannin; the depth of the colour will vary according to the amount of tannin present in the infusion and the strength of the solution of iron.

(2) *To demonstrate the effect of tannin on albumin.* Take 1 litre ($1\frac{3}{4}$ pints) of egg albumin solution (*page* 186), or a similar quantity of a solution of gelatine and divide it into 5 gas-jars (*a*), (*b*), (*c*), (*d*) and (*e*); keep all at a temperature of 38° C. (100° F.) in a water-bath or on a sand-bath. Add 50 c.c. of a dilute solution of tannin to (*a*) and a pinch of bi-carbonate of soda to (*c*). Then add 50 c.c. of the infusion to (*b*) *10* minutes after the tea is made, 50 c.c. to (*c*) and (*d*) *20* minutes after it was made and the same quantity to (*e*) *half-an-hour* after it was made.

Compare the character and amount of any precipitate which forms in the jars (*b*) and (*c*), (*d*) and (*e*), with the coagulated matter precipitated in (*a*). What accounts for the absence of a precipitate in (*c*)?

(3) *To demonstrate the presence of Theine in tea.* Make a very strong infusion of tea (50 c.c. water to 3 grams of tea) and evaporate it very slowly to dryness over a water-bath. Place the dried extract of tea in a small porcelain evaporating basin on a hot sand-bath, of which the temperature must be maintained at 200° C. (392° F.).

Hold a small beaker inverted over the evaporating basin; a white fume will rise and condense in feathery crystals on the cold surface of the glass. This is the alkaloid called *theine* (also known as *caffeine*), the most important constituent of tea.

NOTE.—The quantity of such deposit depends somewhat upon the skill with which the process of evaporation is carried out. If necessary the experiment should be repeated until the minute colourless crystals form in sufficient quantity to be easily identified.

The most important points of difference between Indian and China teas are the relative quantities present of *theine* and *tannin*. Indian and Ceylon teas are richer in both ingredients than China teas, sometimes to the extent of 3%, which constitutes a disadvantage in the case of the former; they are, however, very widely used on account of their usually lower price.

All authorities agree that the composition of the infusion and the method of preparation is of greater hygienic importance than that of the leaves from which the infusion is made. The theine is so soluble that it is dissolved out immediately water is poured on the tea, but it is a matter of common knowledge that the amount of tannic acid increases steadily for ten or fifteen minutes, while other bitter substances present in the tea are also slowly dissolved.

It cannot be too strongly emphasised that boiled or stewed tea is definitely unwholesome; whereas an infusion freshly made with water just "come to the boil" (not become "flat" from prolonged boiling), and poured off the leaves after five minutes into a hot pot is a useful and refreshing beverage, which may be drunk with equal pleasure and advantage by healthy adults three times in the day. When thus prepared, the inhibitory action of tea upon a normal digestion is a negligible quantity except at meat meals, but should circumstances require at any time the consumption of "stewed" tea, milk rather than water should be added to make the beverage more wholesome and less unpalatable, for the albuminous matter present in milk tends to throw down the tannin of the tea in an insoluble form.

The addition of a little bicarbonate of soda to the infusion serves partially to neutralize the tannic acid and to reduce its injurious effects when it is present in large quantities.

The alkaloid present in both tea and coffee acts as a stimulant to the brain and vital centres, removes the sensation of weariness and, from the reflex excitability it brings about, may cause sleeplessness.

The refreshing influence of tea and coffee is probably promoted by the custom of drinking these beverages hot (50° to 60° C.) (122° to 140° F.). Increased diuretic activity results from the stimulus given to the heart's action, which also assists the excretion of waste matters.

Tea and coffee *are in no sense foods*, for they increase rather than diminish tissue waste, but undoubtedly they "oil the wheels of life" when taken with discretion, and promote mental activity as well as relieve physical fatigue.

The volatile oil which gives the peculiar odour to tea and coffee is present in very small quantities, but it appears to act as a stimulant to the brain and heart, though curiously

enough the action of this oil in coffee seems the reverse in some respects of that which is present in tea. For instance, one well-known effect of drinking tea is the increased evaporation which soon takes place from the surface of the body by the dilation of the superficial blood-vessels; whereas after the consumption of coffee no such increased moisture is observable on the skin.

(*B*) *Coffee.*

(1) Pour 200 c.c. of boiling water over 20 grams of freshly-ground coffee, previously placed in a glass jar. Cover immediately, and proceed in all respects as directed in (*A*) (1).

Do your observations confirm the statement that each cup of coffee contains about 3 grains of tannic acid?

(2) *To demonstrate the presence of Caffeine in coffee.* Put a little, fine, freshly-ground coffee into a test tube. Add 5 c.c. ether or benzine, shake the moisture vigorously and stand the tube aside until the sediment has separated and the supernatant liquid is left clear. Pour off this liquid into an evaporating-dish, and allow evaporation to take place over hot water. Test the odour and taste of the residue, of which a small proportion consists of caffeine.

(*C*) *Cocoa.*

(1) Mix 4 or 5 grams of some form of cocoa powder into a paste with cold water in a small beaker. Add 100 c.c. of boiling water, stir and filter off a few c.c. into a second vessel. When cool, test the filtrate with iodine for the presence of starch.

(2) Put a little dry cocoa powder into a test tube, add 3 c.c. of ether or benzine and proceed as directed in (*B*) (2).

The greasy residue left after evaporation is *cocoa butter*; the taste and smell of fat can be quite well detected.

NOTE.—The amount of alkaloid present in cocoa is insufficient to exercise any influence upon the nervous system; it therefore constitutes a wholesome and pleasant beverage for children (to whom tea or coffee should be strictly denied until twelve or fourteen years of age), and for adults who are injuriously affected by tea or coffee.

About one-third of the fat present in cocoa is removed by pressure before it is prepared for sale. From 5 to 15% of starch is present in the cocoa bean and more is often added for purposes of commercial convenience. The tannin present differs in some respects from that found in tea and coffee, while, though the proportion of nitrogenous substances seems considerable, as shown by chemical analyses, only from 20% to 30% of that is present in a form which permits it to be absorbed by the body. In those preparations of cocoa which contain, as most of them do, a high percentage of starch, it is advantageous to boil the cocoa instead of merely mixing it with hot water. (*cf. pp.* 293 and 360.)

COMPOSITION OF COCOAS.

AFTER DR. HUTCHISON.

	Moisture.	Fat.	Nitrogenous Matter (N x 6·25).	Non-Nitrogenous constituents other than Fat.	Ash.
Cadbury's Cocoa Essence ...	3·9	25·2	20·9	45·2	4·8
Fry's Pearl Cocoa	7·3	15·8	4·3	71·2	1·4
Fry's Pure Cocoa	5·6	25·6	19·7	48·2	5·9
Van Houten's Pure Cocoa ...	3·0	28·0	20·5	39·7	8·8
Vi-Cocoa	6·3	26·9	17·0	43·8	7·0
Schweitzer's Cocoatina ...	4·3	28·2	19·4	41·8	6·3
Rowntree's Elect Cocoa ...	6·5	25·5	18·0	42·2	7·8
Epps' Prepared Cocoa ...	4·9	15·1	6·7	71·8	1·5
Suchard's Cocoa	—	—	—	—	—

AVERAGE COMPOSITION OF A PURE SOLUBLE COCOA.

Moisture	4 per cent.
Nitrogenous Matter ...	20 ,,
Fat	26 ,,
Other Non-Nitrogenous Matter	40 ,,
Mineral Matter	—

PROBABLE PERCENTAGE OF NUTRIENTS IN SUCH A COCOA.

Proteid	12 per cent.
Fat	26 ,,
Carbohydrates	25 ,, (?)

VI.—Alcoholic Drinks.

MATERIALS: *Ale; alcohol; Devonshire cider; port wine or sherry, gin or whiskey; sweet oil; castor oil; absolute (pure) alcohol; camphor; red or black ink; salt; bread; raw meat; sprats; white currants; compressed yeast; lime-water; red, blue and neutral litmus paper; strip of gummed paper; taper; filter paper; matches; cotton wool; fine wire; piece of card.*

APPARATUS: *Glass rods; beakers; gas-jars; c.c. measure; thistle funnel; test tubes; small porcelain basins; glass slips; funnel; pipette; thermometer; Würtz flask; rubber corks; glass tubing; retort-stand; Bunsen burner.*

(*A*) *General characteristics of Alcohol.*

(1) Dip a glass rod into some alcohol, and allow a drop to fall on to neutral litmus paper; is the reaction acid or alkaline? Repeat the test using (*a*) blue and (*b*) red litmus paper. Is the accuracy of the first observation fully confirmed, viz.:—that the reaction of alcohol is neutral?

(2) Take two small beakers (*a*) and (*b*) and fill them half full (*a*) with alcohol, (*b*) with water. Compare them as to colour, smell, taste, mobility; (*i.e.*, which of the two liquids flows the more readily when the beaker is tilted and a few drops of the contents are poured into another vessel?)

(3) (i.) Take a third beaker (*c*) of similar size to (*a*) and (*b*) and half fill it also with water. Float 1 c.c. of sweet oil on the surface of (*b*). Colour an equal quantity of alcohol with a drop or two of red or black ink and pour it *very carefully* through a thistle funnel on to the surface of (*c*). It should form a coloured layer on the top of the water.

(ii.) Vigorously stir the contents of both beakers with glass rods and watch the results. What great difference is rapidly perceptible between the two combinations of fluid in (*b*) and in (*c*)?

(iii.) Place 48 c.c. of water in a large test tube, tilt it into a semi-horizontal position and pour 58 c.c. of absolute (pure) alcohol carefully on the surface of the water; mark the level of the mixture with a strip of gummed paper, place the thumb over the mouth of the tube and thoroughly mix the contents by shaking. Observe:—that the tube becomes perceptibly warmer during the process; the rise in temperature being due to the chemical activity associated with the intimate combination which takes place between the two fluids, also that numberless tiny bubbles ascend to the surface of the liquid. Has any change taken place in the level of the mixture as recorded by the strip of gummed paper?

NOTE.—Though the specific gravity of alcohol (= ·792) is less than that of water, of which the specific gravity = 1 (*see page* 68), it nevertheless enters into most intimate union with water, a union accompanied by the production of heat and by a diminution of the original volumes of the two fluids (a reduction equal to about 3·5 c.c. will take place in the total volume of the alcohol and water used in this experiment). These two facts furnish evidence that when water and alcohol are combined they form a compound, not a mixture.

Rectified spirit may be used instead of alcohol in (i.) and (ii.) but it is necessary to use absolute alcohol in (iii.).

(*B*) *The inflammability of Alcohol.*

Take a small porcelain basin (*a*), and place in it 10 c.c. of alcohol. Touch the surface of the liquid with a lighted taper. What colour is the flame? Notice the white luminous tips to the blue flame. This indicates the presence of carbon.

Invert a small beaker rapidly over the alcohol burning in (*a*), and slip a glass slide over the mouth of the beaker when the flame is extinguished, before restoring the beaker to its usual position. Examine the beaker in a good light; is there any sign of a deposit of moisture upon its sides?—a fact which would prove that alcohol contains hydrogen. Fill a pipette with clean lime-water and expel its contents quickly into the beaker; replace the glass cover and shake well; what evidence is afforded of the presence of carbon dioxide gas?

How do these two observations, taken in conjunction with the fact that no residue is left in (*a*), confirm the statement that alcohol, when it burns, is converted entirely into water and carbon dioxide?

Note.—Draw attention to the fact that pure alcohol burns away without leaving any residue. The "dew" deposited on the inverted tumbler is water formed by the oxidation of the hydrogen present in the spirit. The carbon dioxide is the result of the combination of carbon, also a constituent of alcohol, with the oxygen of the air during combustion. Alcohol is the generic name for a class of substances, of which *ethyl alcohol* or spirits of wine is the representative present in fermented drinks. All alcohols are composed of carbon, hydrogen and oxygen, but the proportions differ in each member of the different classes.

Absolute alcohol is pure spirits of wine, a liquid which boils at 78° C. (173° F.). Specific gravity ·792. *Rectified spirits* consists of 90% of alcohol plus water and has a specific gravity of ·83. *Methylated spirits* is composed of about 90% of spirits of wine or rectified spirit mixed with methyl alcohol (poorly purified *wood-spirit*), and petroleum (*see page* 69), which cause it to burn with a more or less luminous flame, and render it too nauseous to be used as a beverage.

(*C*) *Volatility.*

Drop a little alcohol from a pipette on the wrist or back of the hand. What sensation is associated with the rapid disappearance of the liquid from the surface of the skin?

Note.—The heat of the body suffices to vapourize the spirit with great rapidity, and the sensation of cold is caused by this rapid extraction of heat from the surface.

(*D*) *Boiling point.*

Half fill a beaker with water. Arrange it on a sand-bath, over a Bunsen flame. Support a thermometer in the beaker and raise the water to boiling point. Remove the source of heat and immediately plunge a test tube half full of alcohol into the beaker. Does the alcohol boil, in spite of the fact that the water is gradually cooling? Observe

the temperature of the water when the alcohol ceases to boil. What difference is there between the boiling points of the two fluids?

NOTE.—The boiling point of alcohol is 78·4° C. (173° F.). This method of estimating the temperature at which alcohol boils is recommended, in consequence of the great inflammability of the pure spirit if exposed directly to great heat.

(*E*) *Solvent powers of Alcohol compared with those of Water.*

(1) Take two large test tubes (*a*) and (*b*), and place in each some small lumps of salt. Half fill (*a*) with water, (*b*) with alcohol. What effect have the two liquids upon the salt?

Repeat this observation with:—

(i.) lumps of sugar;
(ii.) fingers of bread;
(iii.) piece of raw meat;
(iv.) two small fish, such as sprats;
(v.) some white currants.

Plug the mouths of the six test tubes used for Nos. (ii.), (iii.) and (iv.), with cotton wool; keep the contents of all the tubes under observation for a month.

NOT :.—These experiments will show that the action of water is very different from the action of alcohol. The former is an almost universal solvent, promotes the digestive process and favours the development of life, whereas alcohol renders most substances *insoluble*, coagulates proteid matter and hardens other food-stuffs by virtue of its hygroscopic properties; that is, owing to its great affinity for water, alcohol extracts their contained water from other substances, leaving them in a tough, dried condition, favourable indeed to indefinite preservation but rendering food-stuffs unfit to be dissolved by the digestive juices. This preservative quality is, however, invaluable for keeping all kinds of specimens for scientific and museum purposes.

If coloured fruits are used instead of white currants for the experiment the colouring matter is dissolved out of their skins by the alcohol, so that the results of the experiment cannot be as well observed.

The following series of experiments supplement those already carried out.

(2) Prepare four small gas-jars, (*a*), (*b*), (*c*) and (*d*); half fill:—

(*a*) with a strong solution of common salt;
(*b*) with freshly-made, clear, lime-water;
(*c*) and (*d*) with rectified spirit.

Add small quantities of alcohol to (*a*) and (*b*), a few pieces of lump camphor to (*c*) and a small quantity of castor oil to (*d*).

Record the results obtained in each case.

NOTE.—Some of the salt and lime is precipitated, *i.e.*, thrown out of solution by the alcohol in (*a*) and (*b*) whereas the spirit exercises a solvent effect upon the camphor and would do so with resin or sealing wax if the experiment were repeated with those substances.

Alcohol is of great service in the arts and manufactures because of this solvent power on gums, resins, waxes, etc. It is for many reasons a substance of immense importance in the scientific world, whereas observations and experiments demonstrate that even in small quantities it interferes with the normal physiological functions of the cells and tissues of a living body.

(*F*) *Alcohol the product of Fermentation.*

(1) Take a large glass jar (a 2-lb. jam jar answers the purpose well), and place in it about 28 c.c. (1 oz.) of golden syrup, glucose or brown sugar, add one-third the quantity of flour, and mix both well by stirring into them 300 c.c. of lukewarm water.

Crumble some compressed yeast into the jar and stir the contents again. If the consistence of the mixture is very thick and glutinous a little more water must be added or the yeast will not "work." Cover the jar with a slip of card or glass and keep it under observation at a temperature about 20° to 25° C. (68° to 77° F.) for some hours.

There should be evidence of fermentation after half an hour, *i.e.*, the liquid will be in a condition of constant motion, bubbles of gas forming and rising quickly to the surface.

(2) (*a*) When all signs of activity have ceased, light a taper and move the cover sufficiently aside to plunge the taper into the upper part of the jar. Does it continue to burn? (Air, IV., (*A*), *pp*. 53-4.)

(*b*) To prove that it is the presence of carbon dioxide gas which extinguishes the taper, twist two short lengths of fine wire round and immediately beneath the slightly rolled rim of a very small glass beaker or tin cup to form two handles, then suspend the little vessel in the upper part of the glass jar, by passing the free ends of the wire through a piece of card, which should be employed as a cover to the jar, and fixing them like clips to the neck of the jar.

Leave the little beaker or cup in position for twenty or thirty minutes, then raise the cover and expel into it the contents of a pipette full of lime-water. The turbidity of the lime-water will at once indicate the presence of carbonic acid gas, which has found its way into and filled the vessel.

Note.—Yeast cells during their growth and multiplication set up a chemical change in sugar solutions, so that in the process of alcoholic fermentation the sugar disappears to reappear as alcohol, while the carbon dioxide gas which forms escapes as bubbles of gas into the air.

Sugar and alcohol are built up of precisely the same elements (carbon, hydrogen and oxygen), though they differ from each other in the proportion of these elements. Fermentation is practically a change of relative position among these elements; a change which if expressed in chemical formula would read as follows:—

$$C_6\,H_{12}\,O_6 \text{ plus the yeast} = 2\,C_2\,H_6\,O + 2\,CO_2.$$

The limit of fermentation is reached when the fermenting fluid contains about 14% of alcohol, because a higher proportion of alcohol is injurious to further action by the yeast plants, which become poisoned by the products of their own growth. In the manufacture of fermented drinks from cereal grains containing starch there is a double chemical process. (1) The starch present in the cereals is changed into sugar by *conversion*. (2) The sugar so produced is changed into alcohol and carbon dioxide by *fermentation*.

(3) Support a glass funnel in a Würtz flask; plug the second nozzle with cotton wool, and filter the liquid from the glass jar into the flask, until it is half full. When the process of filtration is concluded, remove the funnel, close the mouth of the flask with a rubber cork and arrange it as in *Fig.* 15 (*page* 71). The receiving flask should be three-fourths immersed in a vessel of the coldest water obtainable, and a pad of filter paper, soaked in cold water, should be laid over the uncovered portion of the flask. Light the Bunsen burner under the Würtz flask and proceed to distil off the alcohol (produced by the process of fermentation) from the filtrate contained in the flask. Drops of clear liquid will gradually condense in the receiving flask. Continue the process until several c.c. of fluid have collected; this consists of alcohol and water.

Remove the receiving flask from the basin, disconnect it from the Würtz flask and close its mouth with a cork *before* extinguishing the flame.

(4) To prove the presence of alcohol in the distillate (*i.e.*, the liquid in the receiver), pour it into a smaller flask, support this on a retort stand over a Bunsen burner, and close the mouth with a rubber cork through which passes a straight piece of glass tubing from 40 to 50 cms. (16 to 20 ins.) long.

Heat the distillate very gently, and as the temperature rises apply a lighted taper to the mouth of the tube at frequent short intervals. The appearance of a blue flame will indicate that alcohol is being driven off from the distillate. Remove the source of heat when this occurs. How do you explain the fact that the liquid ceases to burn before all the fluid in the flask is exhausted?

NOTE.—The alcohol rapidly evaporates as the liquid is warmed, and ignites, but combustion continues a very short time in consequence of the small amount of alcohol present in the distillate, of which the residue is water.

(5) *To prove the presence of alcohol in Ale by a similar test.* Half fill a flask with ale, arrange it, and proceed in every respect as directed in (4).

Just as the liquid boils apply a light to the mouth of the tube, and a flame of greater or less duration will result according to the proportion of alcohol present in the ale.

(6) To prove this statement take four flasks, (*a*), (*b*), (*c*) and (*d*). Place in :—

(*a*) 100 c.c. of the same ale used in (5).
(*b*) 100 c.c. of Devonshire cider.
(*c*) 100 c.c. of port wine or sherry.
(*d*) 100 c.c. gin or whiskey.

Fit up each as directed in (4) and apply a lighted taper to the mouth of each flask as its contents begin to boil. The flame will vary in size and duration according to the proportion of alcohol present in the contents of each flask.

NOTE.—Better results are obtained with ale and sparkling cider if they are vigorously shaken before being used for the experiment, and are then allowed to stand until the liquid is free from bubbles. This treatment expels a large amount of the carbon dioxide gas.

Malt liquors contain from 5 to 10% of alcohol, cider contains from 2 to 6%, wines contain from 10 to 20%, and spirits from 30 to 60%.

For an exhaustive and fair-minded treatment of the whole question of the physiological effects of alcohol as a beverage or as a drug, reference should be made to Chapter XIX.—"*Food and the Principles of Dietetics,*" *Dr. R. Hutchison (Arnold, London).* Here it is pointed out :—

(1) That the local effects of alcohol upon the mucous membranes of the body are those of a *chemical irritant,* they also become "corrugated" and whitened by reason of the removal of water from the surface cells and the coagulation of their protoplasm.

(2) Taken in more than very small quantities alcohol *retards* digestion, consumed in large quantities it *arrests* the process owing to the general nervous and vascular depression which it brings about.

(3) Alcohol is very rapidly absorbed by the stomach, hence its value as a *restorative* in conditions of shock or exhaustion, when life is threatened and all digestive power is in abeyance; its use should, generally speaking, be entirely confined to such occasions.

The powerful *reflex* as well as *direct* effect of alcohol on the heart is borne witness to by the cases of sudden death which occasionally follow upon the consumption of large quantities of spirits on an empty stomach. The nerves of the stomach are in very close relation to those which control the heart's action, and the reflex action through the medium of the nerves of the stomach actually suffices under such circumstances to stop the heart's beat entirely.

(4) Professor Bunge has pointed out that "Alcohol invariably exercises a paralysing influence upon the human nervous system. All the results which to the ignorant or superficial observer appear to show that alcohol possesses stimulant properties can be explained on the ground that they are due to *paralysis*." For example:—

(*a*) The feeling of *increased warmth* in the skin which follows the consumption of alcohol is the result of a partial paralysis of the central nervous system, namely of those nerves which control the calibre of the superficial blood vessels of the skin. The central organs of sensation are also probably blunted, so that sensation is no longer normal.

(*b*) The apparently *stimulating action* of alcohol on the physical functions is explained by the fact that the powers of judgment and criticism are hampered, not increased, the emotional life comes into freer play, so that dangers and difficulties are no longer realized as is the case when the mind is working in full possession of its powers of judgment.

(*c*) The *temporary alleviation* of mental suffering, of pain or of anxiety are due to the same cause.

(*d*) The lively gesticulations associated with the early stages of intoxication are the result of *loss of control* over the inhibitory or higher brain centres, there is consequently a foolish waste of strength coupled with a childish want of self-restraint.

(*e*) The sensation of having received a stimulus may be explained by the fact that the sense of fatigue is *deadened*, whereas fatigue is one of the body's safeguards against over exertion and it should not be disguised or neglected.

(5) Alcohol acts as *fuel* in the body it is true and to that extent it is a food; but as either food or fuel it is of the most extravagant, unsuitable and unsatisfactory character, for, as

a result of its paralyzing influence on the vaso-motor nerves and the coincident dilation of the surface blood vessels more heat is given off from the skin by radiation than is produced by the combustion of the alcohol in the body; so that the result is a serious loss and not a profitable gain to the organism.

Impress the fact that alcohol does not "keep out the cold" but allows the heat of the body to escape to excess. Thus drunkards in conditions of advanced intoxication are liable to die of cold when exposed to frost or other severe atmospheric conditions, such as biting winds or drenching rain, on account of the rapid radiation of heat from their bodies. The paralysis of the vaso-motor nerves by alcohol means that the compensating and regulating mechanism which is usually actively at work maintaining the normal temperature of the body, is in abeyance. This mechanism contracts the capillaries if the weather is cold and keeps the blood warm in the interior of the body, while in hot weather it relaxes the capillary muscles and allows a larger proportion of the blood to lower its temperature on the surface. Sensation is, however, localized in the skin, consequently when the skin is flushed as the result of drinking alcohol, the individual feels warm, though actually he is becoming rapidly cooler, until, in extreme cases, his body temperature is diminished below that necessary to the maintenance of life.

(6) Alcohol, in excess of the very small amount which can be oxidized in the body without directly deleterious effects, *paralyzes* other cells besides those of the nervous system, interferes with the normal processes of tissue change, impairs nutrition and predisposes the constitution to chronic disease.

It must also be remembered that the habitual consumption of alcohol in quantities, insufficient indeed to cause any outward signs of intoxication yet beyond the immediate oxydizing power of the body cells, may, and too often does, end by playing havoc with the tissues. In fact all the functions of the body are best performed in the absence of alcohol, though in disease it has its uses.

(7) Total abstainers, other conditions being equal, possess greater immunity from disease, greater powers of endurance, and are more efficient workers than are the rest of the population.

(8) Alcohol exercises a most pernicious effect upon the offspring of parents other than the most moderate drinkers of alcohol, rendering such children liable to a series of moral, mental and physical ills too numerous to detail, but disastrous to the individual sufferers and to the welfare of the nation.

The serious prevalence of alcoholism in this country at the present time renders it imperative to bring the results of its habitual and excessive consumption before all young people, so soon as they are old enough to understand the degradation which follows its abuse and the responsibility which devolves upon all those who, by influence or example, perpetuate one of the most grave menaces to national efficiency.

XIX.—TESTS FOR THE QUALITY OF FOOD-STUFFS.

Household tests for meat, eggs, butter, flour, pepper, sugar, glucose, coffee. Detection of metallic salts in preserved vegetables. Detection of aniline dyes in sauces and confectionery. Analysis of egg powder.

I.—Household Tests for "suspicious" Articles of Food.

MATERIALS: *Fresh and slightly tainted meat, sausages and eggs; butter; margarine; flour; bread or cake; pepper; salt; sugars (white, brown, granulated, etc.), jams or jellies; pure ground coffee and chicory; milk; powdered alum; iodine; lime-water; ammonium carbonate solution; solution of logwood; alcohol; hydrochloric acid; filter paper; butter muslin; neutral litmus paper; ice; water.*

APPARATUS: *Beakers; test tubes; funnels; bowls or dishes; glass and wooden rods; thermometer; c.c. measure; sharp knife; retort stand; Bunsen burner.*

(*A*) *Meat.*

(1) Take about 30 grams (1 oz.) of meat, of which some doubt exists about the freshness or good condition. Mince it finely, place it in a beaker or bowl and drench it with warm water, 45° C. (113° F.). Take a deep sniff from the vessel before and after the addition of the warm water. If the meat is even slightly tainted the characteristic odour will become apparent after this treatment.

(2) Dip a slip of neutral litmus paper into the liquid in the vessel, bringing it into close contact with the meat. If there be no reaction, or if the reaction be alkaline, the evidence by odour will be fully confirmed. Fresh, wholesome meat gives a slightly acid reaction when tested with litmus paper.

(3) Repeat (1) and (2) with a small piece of very fresh meat and compare the observations made in the two cases.

(4) Boil a sausage in water, remove it from the vessel, cut it open and pour over it a few c.c. of freshly made lime-water.

If the sausage be tainted a most unpleasant odour will result from this treatment.

(*B*) *Eggs.*

(1) Make some brine by dissolving 60 grams (2 oz.) of salt in 500 c.c. (about 1 pint) of water. Pour the brine into a large beaker or gas-jar, then drop in gently, one by one, any eggs (in their shells) of which it is desired to test the freshness.

A fresh egg will sink, a stale one will float. A stale egg floats more or less buoyantly in brine according to the amount of gas formed in the process of putrefaction. Such fermentation is brought about by the micro-organisms present in the egg before the shell was formed, or which gained admission through the pores of the shell after the egg was laid.

(2) Hold up an egg between the eye and a bright light, preferably artificial.

If the egg be fresh, a perfectly uniform translucent tint will pervade the whole egg, except the air-chamber at one extremity; this should only occupy about $\frac{1}{20}$ of the contained area; there should be no dark spots visible in any part of the egg.

If the egg be stale the colouration will be more or less cloudy. The appearance is darker and more or less opaque according to the increasing rottenness of the egg.

NOTE.—Definite practical instruction should be given to elder boys and girls upon the necessity for caution in the selection of food, both animal and vegetable, and of the indications of good condition in those most commonly purchased. The characteristics of good meat should be thoroughly learned in this way, as well as such facts as that after hanging for a day or two meat should become drier, not more moist. When dried at 100° C. (212° F.) unsound meat will often lose 80 % of its weight, whereas sound meat will only lose from 70 to 74 %.

The method for testing the freshness of eggs given in (2) is familiarly known as "candling" and is used habitually by dealers. It is best to darken the room and to hold the egg between the eye and some source of artificial light.

In a stale egg the small air-cell is obliterated and presents the same appearance as the rest of the egg, whereas in a fresh egg it is distinctly transparent. In stale eggs the yolk and the white slightly intermingle along the point of contact, and when the eggs are broken a somewhat musty odour may be noticed.

(*C*) (1) *To distinguish genuine Butter from Margarine.*
(*Waterhouse Test.*)

(i.) Place 250 c.c. (about ½ pint) of fresh milk in a shallow bowl or dish and set it aside in a cool place for about 12 hours. Then skim off the cream as completely as possible.

(ii.) Take two cups or beakers, (*a*) and (*b*), of a capacity of 250 c.c. (½ pint). Half fill each vessel with this fresh skimmed milk; arrange them on a water-bath over a Bunsen burner and raise the temperature of the milk to nearly boiling point, 91° C. (196° F.).

(iii.) Add to (*a*) about 6 to 8 grams of genuine butter, and to (*b*) an equal amount of margarine.

(iv.) Stir the contents of each vessel with wooden rods, about as thick as an ordinary match, until the milk boils up. Immediately transfer both vessels to a pan or bowl previously filled one-fourth full with pieces of ice, which must be packed closely round the bottom of the beakers or cups. The

melting ice must not reach outside the vessel to more than a quarter of the depth of the milk within, any excess of ice or water in the pan must be removed; though naturally the level of the liquid will be raised gradually as more ice melts.

(v.) Continue to stir the contents of the vessels for ten minutes with the wooden rods, but pause once in every minute to stir the ice and water in the pan, by moving them about in a circle, following the edge of the pan. The contents of (*a*) and (*b*) must be rapidly stirred with an alternately cross-wise and rotary movement, except for the momentary pause necessary during the stirring of the ice and water in the pan.

(vi.) Continue the stirring process for ten minutes, more or less, *i.e.*, until the fat in (*b*) has gathered, or has allowed itself to be gathered, into a soft clot.

Meanwhile the butter in (*a*) will have emulsified with the milk and can by no means be formed into a homogenous mass, no matter how long the effort to do so may be sustained.

NOTE.—This Waterhouse or "Milk" test for the purity of butter is based on the assumption that butter-fat, which is in itself exclusively the product of milk, will mingle intimately with milk when added thereto in a melted condition and cooled therein.

Oleomargarine, on the other hand, which consists chiefly of fats foreign to milk, will under like conditions, refuse to diffuse itself naturally in milk as a medium. Even after cooling, genuine butter-fat shows a strong tendency to form an emulsion with milk when stirred steadily therein, and is slow to rise to the surface. "Renovated" butter-fat, *i.e.*, butter made from a miscellaneous assortment of any kind of butter which, by too long keeping, or by unfavourable conditions of dirt or temperature has suffered deterioration, but by skilful manipulation has had its unsatisfactory character disguised, almost instantly gathers in a film on the surface of cold milk after it has been well stirred. Such butter does not clot like margarine, but adheres to the wooden rod with which it is stirred.

(2) *To distinguish Genuine Butter from Margarine.*

(i.) Take two large test tubes, (*a*) and (*b*); put in (*a*) from 6 to 8 grams of fresh butter, in (*b*) a similar quantity of margarine.

(ii.) Melt both samples over a Bunsen burner, stirring meanwhile with wooden rods similar to those used in (i.).

(iii.) When the fat is melted in both test tubes bring their contents quickly to boiling point; stir briskly during the process, especially just before the boiling ceases.

Compare the phenomena associated with boiling in the two tubes.

NOTE.—In (*a*) the butter will foam very freely, but makes little noise. In (*b*) the margarine sputters and boils noisily, though it produces little foam. The difference in respect of the amount of foam produced is very marked, it is usually abundant in butter, small in amount in renovated butter and entirely absent (or nearly so), from margarine. Renovated butter and margarine both boil noisily, in the same way as a mixture of grease and water.

(3) *To distinguish Genuine Butter from Margarine.*
(*Another Test.*)

Arrange two small beakers (*a*) and (*b*) in a water-bath, and add 6 or 8 grams of butter to (*a*) and a similar amount of margarine to (*b*). The water, with some curd and salt, will gradually settle to the bottom of the beakers.

Prepare two filters with filter paper and filter off the clear fat into two more beakers (the temperature of the fat during filtration should not exceed 50° C. (122° F.). Then inhale the odour from the two specimens of melted and filtered fat. That from (*a*) will give off the pleasant butyric odour associated with genuine butter. This will be absent from (*b*) but a distinctive meaty smell will be evident, in no way unpleasant, but quite unmistakable and peculiar to itself.

NOTE.—Margarine is made by melting down and clarifying various animal fats, chiefly that of the ox, in such a way that the more solid constituents, the stearine and the palmitin, are removed, leaving the olein, or that form of fat which very closely resembles butter. This is churned up with a little milk, suitably tinted with vegetable colouring matter and is then ready for use.

Margarine and butter are almost equally well absorbed by the system, and as the former is now made under the most strict supervision, and as its flavour is practically undistinguishable from butter, there is no foundation for the popular prejudice against its free consumption on hygienic grounds. From the economic standpoint it is inexcusable to retail margarine at the price of genuine butter, and it is chiefly on this account that every householder should learn how to distinguish the one from the other. Very stringent regulations to prevent the perpetration of this and similar frauds are advocated in the Report of the Royal Commission, which was appointed to consider the better conduct and control of the trade in butter and butter-substitutes.

(*D*) (1) *Test for the quality of Flour.*

(i.) Mix 20 grams of flour with a little lukewarm water in a small bowl. Stir the mixture with a glass rod to the consistency of dough; enclose this in a muslin bag, and wash out the starch by kneading the dough in water. Remove the residue from the bag, and try to draw it into fine threads. If these break easily and in short lengths the quality of the flour is poor; if long, tenacious threads can be formed the flour is of a good quality.

(2) *Test for the presence of Alum in flour.* (Logwood Test.)

(i.) Mix 50 grams of flour with 50 c.c. of distilled water, preferably in a glass beaker. Secure an alkaline reaction to litmus paper by the addition of 5 c.c. or more of a solution of ammonium carbonate. Set the mixture aside for a few minutes.

(ii.) Take 50 grams more of the same flour with which a pinch of powdered alum has been previously mixed; then proceed in all respects as in (i.).

(iii.) Add 5 c.c. of a *freshly prepared* solution of logwood to each beaker containing the dough made from the flour and water mixture, then set this dough aside to dry.

The colour in (i.) will become a dirty brownish-pink, in (ii.) it will assume a shade of lavender blue, more or less pronounced according to the amount of alum present in the flour.

NOTE.—In submitting specimens of flour to this test it is a wise precaution, if any blue colouration develops upon the addition of the logwood solution, to set the mixture aside in a warm place for two hours. If any tinge of lavender blue persist at the end of this time the presence of alum may be justly inferred.

Alum is added to inferior flour to give a white colour to bread and to improve the coherency of the dough. There is a general opinion that alum is more or less injurious to the system, and Liebig states that it renders the gluten of the flour insoluble, thus interfering with the process of digestion. Other processes for bleaching flour are now employed, so that the temptation to use alum is less strong than formerly.

Self-raising flours are liable to contain a certain amount of alum, as an excess is sometimes present in commercial baking powders. This test should be applied occasionally to these flours, or, if necessary, to the cakes in the manufacture of which they are chiefly employed. In the case of bread or cakes the procedure should be as follows:—

(3) *Test for Alum in bread or cakes.*

Prepare a mixture of 50 c.c. of distilled water, 5 c.c. of fresh logwood solution, and 5 c.c. of a solution of ammonium carbonate; place this in a bowl or beaker, and immerse in it for 5 minutes about 10 grams of the suspected bread or cake.

Pour off the liquid and dry the specimen at a low heat over a sand-bath.

If no alum be present the bread or cake will become a brown colour, if there be any alum a tinge of lavender blue will reveal its presence.

NOTE.—The chief adulterations in flour are *alum*, *potatoes*, *copper sulphate* and *lime*. Potatoes and cereals are most easily detected with the microscope, which facilitates discrimination between the various starch grains. Alum and copper sulphate are both used with a similar object, *viz.*, to enable white bread to be made with a low grade of flour.

Lewis and Balfour recommend the following test for copper sulphate in bread, 1 part of which in 10,000 of flour is said to suffice to whiten it:—A glass rod is to be dipped in potassium ferrocyanide and drawn across the surface of a slice of the suspected bread; a brick-red streak indicates the presence of this adulterant.

(*E*) *Test for the quality of Pepper.*

Take 2 grams of ground pepper in a small porcelain bowl and cover with concentrated hydrochloric acid. Pure pepper becomes yellow, whereas most foreign ingredients remain uncoloured; these may be *sand*, *mineral matters* or *palm-nut powder* for instance.

Linseed, ground rice, rape seed or similar adulterants of pepper are detected with the microscope.

NOTE.—Spices and other aromatic substances are generally classified as "condiments," they are more or less expensive and lend themselves readily to adulteration or to sophistication when ground to powder. It is advisable therefore, when possible, to buy such articles unground.

Condiments possess no food value, but by their flavours they lend savour and attractiveness to foods, without which certain kinds, such as green vegetables, stews, gingerbread or milk puddings, often fail to stimulate the flow of the digestive juices. Used with moderation they constitute a valuable assistance in the art of good cooking.

(*F*) *Test for the quality of Sugar.*

(1) Take 5 grams of several specimens of sugars, white, brown, crystallized, granulated, etc.; place each specimen in a large test tube. Fill up these test tubes with hot water. How will the result of making this solution assist you to form an opinion as to whether any foreign matter has been added to these sugars?

(2) Take 2 grams of several specimens of brown sugar, each in a separate test tube or small porcelain bowl. Pour a few drops of concentrated hydrochloric acid on to the surface of each specimen. If a red colour develops in either vessel it bears witness to the fact that the sugar has been coloured with yellow or yellow-brown aniline dye.

NOTE.—The risk of adulteration in sugar is small in consequence of its cheapness. If, however, *sand* or insoluble matters have been added their presence will be apparent in (1) when the sugar is dissolved in water.

Some moist sugars are dyed to the particular colour in demand; but the aniline dyes employed for the purpose are easily detected by the method directed in (2).

(*G*) *To detect Glucose in Jams or Jellies.* (Bigelow and Howard.)

Take several specimens of cheap jams or jellies and submit each in turn to the following test:—

(1) Dissolve the jam, marmalade or jelly by standing the jar in hot water. In the case of the two former, the jam or marmalade must be filtered through double butter muslin in order to separate the insoluble material; allow the solution to cool.

(2) Take 20 c.c. of the cool solution and add an equal volume, or rather more, of alcohol.

If the sample is a pure fruit product the addition of alcohol causes no precipitation, except that a very slight amount of proteid bodies is thrown down. If glucose has been employed in its preparation a dense white precipitate separates, and after a time settles to the bottom of the liquid.

NOTE.—There is no reason to believe that glucose is unwholesome or in any way inferior in healthfulness to cane sugar, but, again for economic reasons, the public should not pay the higher price necessary for preserves prepared with cane sugar, golden syrup, or pure honey if this cheaper substitute be used.

Commercial glucose is obtained by treating starch with diastase or dilute sulphuric acid (*page* 302). The product always contains considerable proportions of those easily assimilable forms of sugar, *maltose* and *dextrine*. Measures are subsequently taken to neutralize the acid, which, with

the agent used for this purpose (generally lime), is then removed in the form of sulphate of calcium. If, however, sulphuric acid made from arsenical pyrites is used in the process, the glucose may contain sufficient arsenic to cause serious illness. Otherwise glucose forms a wholesome and useful constituent of cheap confectionery and preserves.

(*H*) *To detect Chicory in Coffee Mixtures.*

(1) Prepare three small bottles or flasks (*a*), (*b*) and (*c*), each half full of water. Place in :—

(*a*) 2 grams of pure ground coffee;
(*b*) 2 grams of ground chicory;
(*c*) a mixture of coffee and chicory such as is usually sold.

Shake each flask for a moment, and then stand them side by side on a flat surface and watch the behaviour of the three samples in (*a*), (*b*) and (*c*).

NOTE.—The greater proportion of the coffee will float in consequence of the large amount of oil present in the berry, 13 to 13·50%, though if the coffee has been over roasted it may sink; as a rule, however, but a small proportion of the whole fails to float or to maintain its firm consistence.

Under ordinary conditions, chicory and all other coffee-substitutes (such as roasted and ground cereals) absorb water quickly and sink to the bottom of the liquid, while streaks of brownish red colour indicate the course of the particles as they fall. A rough estimate may be made of the relative proportions of coffee and chicory in (*c*) by comparing the amount of dregs which collect, as the chicory sinks, with the scum formed by the coffee which floats.

Cases are on record where, in order to defeat this test, chicory has been treated with fat. Where extensive adulteration is suspected it is a wise precaution to supplement this test by the two which follow, though examination with the microscope is also necessary before an absolutely certain opinion can be formed.

(2) Take a gram of each of the three specimens used in (1) and place a few grains of each between the teeth in succession.

The particles of coffee will be found much harder than those of chicory; the latter have also a sweetish flavour and they yield readily to pressure.

When these characteristics have been well realized, practise with the mixture used in (*c*) until the teeth can detect the difference in the degree of resistance offered by coffee or its substitutes when placed between the teeth.

(3) Take 5 grams of the coffee mixture used in (1), boil it with 10 c.c. of water, and filter.

Test the filtrate with iodine for starch (*page* 173), for many of the common adulterants are of starchy nature. A dirty blue reaction is a clear proof that some form of adulteration has been practised.

NOTE.—One pound of chicory at 3½*d*. is equal in colouring power to 2·8 pounds of coffee at 1*s*. 5*d*. As a rule, French coffee contains about one-third of its weight of chicory, but sometimes the proportion may be as high as 80 per cent., or even more.

II.—Detection of Metallic Salts in Preserved Vegetables.

(Bigelow and Howard.)

MATERIALS: *Tinned or bottled peas; hydrochloric acid; bright knitting needle.*

APPARATUS: *Bowl or mug; strong spoon; beakers; pipette; wooden rod; water bath; retort stand; Bunsen burner.*

(1) Take a few grams of tinned or bottled peas and mash them well in a bowl or a mug with a strong spoon.

(2) Transfer 3 grams of this pulp to a beaker with 9 c.c. of water and add 30 drops of strong hydrochloric acid by means of a pipette.

Set the beaker in a water bath containing boiling water over a Bunsen burner.

(3) Stand a bright knitting-needle in the beaker, and boil the water in the bath for 20 minutes, stirring the contents constantly with the needle. Examine that part of the needle that has been in the liquid; if copper be present in an appreciable amount this part will be heavily coated with copper.

NOTE.—"The green colour of peas and beans and other green vegetables which are preserved by sterilization, is fixed by the use of zinc and copper salts. These bodies act as a mordant, entering the tissues of the green plants and fixing the chlorophyll, by preventing its transformation into xanthophyll, which would otherwise occur on long keeping. Green peas which are pasteurized without the addition of zinc or copper become yellow by the production of xanthophyll, while if zinc or copper salts be employed the green colour is preserved indefinitely. It is well known that zinc and copper salts are not particularly wholesome, hence their use in preserved vegetables is to that extent reprehensible."

III.—Detection of Aniline Dyes in Sauces and Confectionery.

MATERIALS: *Pure white worsted or pure white nun's veiling; tomato sauce; tomato catsup; mushroom ketchup; cheap jams or jellies; soda; hydrochloric acid; neutral litmus paper; household ammonia.*

APPARATUS: *Beakers; pipette; small porcelain bowls; wooden rod; sand-bath; retort stand; boiling water.*

(1) Boil a skein of pure white worsted or several narrow strips, about 2·54 cms. wide by 23 cms. long (1 inch by 9 inches) of pure white nun's veiling:—

(*a*) in a very dilute solution of washing soda;

(*b*) in plain water; in order to remove any trace of grease or fat.

(2) Take about 50 c.c. of tomato sauce in a beaker, and slightly acidify it with just enough hydrochloric acid to give an acid reaction with litmus paper.

(3) Immerse a strip of the boiled nun's veiling or two or three strands of the boiled wool in the sauce and raise the temperature to boiling point over a Bunsen burner.

(4) Pour off the boiling water and wash the wool, first with hot water and then with cold. Squeeze the water out as thoroughly as possibly from the wool, and note the colour of the material.

If no marked colour is produced the specimen tested may be considered free from artificial colouration. If on the contrary the fabric is decidedly tinted it is necessary to decide to which of the following sources it must be traced:—(*a*) coal-tar dyes; (*b*) some foreign vegetable colour; (*c*) if a fruit product, the natural colouring matter of the fruit.

Proceed therefore as follows to distinguish (*a*) from (*b*) or (*c*):—

(i.) Rinse the fabric in hot water and then boil it for three minutes in 1 in 10 solution of household ammonia.

(ii.) Remove the material from the vessel containing the solution and free it as completely as possible from ammonia by means of squeezing or wringing.

Usually the fabric will remain coloured if the source be natural, as in fruits, while coal-tar dye will dissolve and tint the solution in which it was boiled.

(iii.) Stir the liquid in the beaker with a wooden rod and add hydrochloric acid from a pipette until the ammonia has been slightly acidified, which should be proved by the reaction given by litmus paper. The odour of ammonia should also be entirely dispersed.

Boil a second sample of the prepared wool or nun's veiling in this liquid, and wash it in hot and then in cold water as directed for the first sample. If the fabric be distinctly coloured there is no doubt that the sauce under examination is artificially coloured.

NOTE.—A few vegetable colours and cochineal will dye wool directly. Most vegetable colours turn green when treated with ammonia, whereas colours derived from coal-tar usually turn blue or purple. In any case, if more than a dull, faint tint persists after the second piece of wool has been tested, which is unlikely to be confused with the vivid hues of aniline dyes, sufficient evidence is afforded of artificial colouration.

This experiment should be repeated with tomato catsup, mushroom ketchup, cheap jams or jellies, or other substances used as food which are brightly coloured. But solids, or substances containing insoluble matters, must be first dissolved in water, either hot or cold, and then strained through butter muslin in order to separate insoluble portions; the filtrate in each case being used for the testing purposes.

IV.—Analysis of Egg and Custard Powders.

MATERIALS: *Three samples of egg or custard powders; iodine; Millon's reagent; 1% solution of osmic acid.*

APPARATUS: *Beakers; retort stand; Bunsen burner.*

Select three examples of the various egg or custard powders sold by most grocers.

Make a few grams of each sample into a solution with water, about 100 c.c. will suffice. Label the samples (*a*), (*b*) and (*c*); divide each into three portions and test these respectively for the presence of starch with iodine (*page* 173), of proteid with Millon's reagent and the Biuret test (*pp.* 168-9), and of fat with 1% solution of osmic acid (*page* 175).

Do the results obtained corroborate the following analysis of well-known custard powders published some years ago in *Food and Sanitation*.

	Hen's Egg.	No. I.	No. II.	No. III.
Starch	—	86·25	81·45	26·38
Albuminous Compounds ...	14·8	0·59	0·58	2·96
Soluble Colouring Matter...	—	0·88	0·90	—
Baking Soda	—	—	—	50·7
Tartaric Acid...	—	—	—	10·33
Water	73·7	11·83	11·0	9·63
Ash	1·0	0·45	0·38	—
Fat	10·5	—	—	—

NOTE.—The adulteration of food may be roughly divided into two classes. (1) Additions or substitutions used with the object of reducing the price at which the preparation is retailed, the results of which are rather economic than hygienic.

(2) Colouring or other matters employed to make foods more attractive or to make substitutes more closely resemble the article they replace. The use of preservatives should be unquestionably restricted to cases where their judicious use is manifestly demanded, and each article of food should be labelled or branded in regard to the character and quality of the preservative employed.

XX.—METHODS OF FOOD PRESERVATION.

Some causes of decomposition in foods. Conditions which affect the preservation of foods. Methods of food preservation in common use.

I.—Some Causes of Decomposition in Foods.

MATERIALS: *Raw meat; cooked meat; flour; sugar; fresh green peas; dried peas; butter; eggs; clear soup stock; milk; lemons; apples; cherries; tomatoes; well ripened cheese; nutrient gelatine; filter paper; cloth.*

APPARATUS: *Test tubes; shallow dishes or bowls; thermometer; c.c. measure; Petrie dishes; slips of glass; funnel; beakers; good hand-lens; large bell-jar; knife; retort stand; Bunsen burner.*

(1) Prepare eight test tubes, (*a*), (*b*), (*c*), (*d*), (*e*), (*f*), (*g*), (*h*), and proceed as follows. Put in :—

(*a*) a piece of raw meat.
(*b*) a piece of cooked meat.
(*c*) 5 grams of flour.
(*d*) 5 grams of crushed sugar.
(*e*) 5 grams of fresh green peas.
(*f*) 5 grams of dried peas.
(*g*) 5 grams of butter.
(*h*) 5 grams of white of egg (albumin).

Set all the tubes aside in a warm place, about 20° to 25° C. (68° to 77° F.), for a few days.

What conclusions are to be drawn from subsequent observations as to the tendency to putrefaction in different foods? What types of food are most liable to decay; what conditions are common to all those which putrefy most readily?

(2) Place about 28 c.c. (1 oz.) of clear, cool soup stock in a small shallow dish or bowl, and expose it to the air for a few hours in an unoccupied room; then cover the vessel with a piece of clean glass and set it aside in a rather warm place. Examine the contents every day for a week. Does the appearance of its surface gradually resemble that of the nutrient gelatine (after the same lapse of time) which was used in the experiments on "AIR," IV. (*B*), *pp.* 55, 56; "WATER," IV. (*B*) (2), *page* 72; or "MILK," (*G*), *page* 387.

(3) Place in a beaker a few c.c. of juice squeezed from any kind of ripe fruit. The juice should be passed through a filter if not free from particles of pulp. Collect a little dust from the floor, the cornices of the room, the book shelves or some other dusty surface, and sprinkle it over the surface of the juice; cover the beaker with a slip of glass or fasten a piece of cotton wadding over its mouth, held in position by a rubber band, and set it aside in a warm place. Watch any changes which take place in the juice daily for a week; then examine the surface with a good hand-lens.

A luxuriant growth of moulds and yeasts will gradually develop, the seeds and spores of which were present in the dry and apparently lifeless dust.

(4) Expose a few c.c. of milk to the air for a week, preferably in a small shallow bowl. How soon does the milk become obviously unfit for food? (*cf.* "THE STUDY OF MILK," I. (*F*), *page* 385).

(5) Lay two lemons (*a*) and (*b*) on a shelf in a warm room, wipe them very dry with a clean cloth, but slightly moisten the skin of (*b*) in one or two spots on its surface. Examine the lemons each day for any change in their conditions.

When moulds have developed on (*b*) cover both (*a*) and (*b*) with a large bell-jar, or enclose them in a tin or wooden box. Does the growth spread from (*b*) to (*a*)? What lesson does this teach upon the necessity for watchful care over the contents of a larder or store-cupboard?

(6) (i.) Take three sound apples, cherries, tomatoes or other fruit, characterized by firm, protective skins; label them (*a*), (*b*), (*c*), and wipe them carefully.

Bruise (*a*) by allowing the fruit to fall or by applying hard pressure. Make a small incision in the skin of (*b*); then set all three specimens aside for a week, under the same conditions but not in contact one with the other. Compare the appearance at the end of that period. What conclusions are to be drawn as to the causes which predispose fruits and vegetables to decay?

NOTE.—Decay will be more or less advanced in (*a*) and (*b*), (*c*) may be slightly shrivelled, but should be sound in all other respects, if the skin were uninjured at the commencement of the experiment.

(ii.) To prove that the decayed substance in these specimens is living matter, proceed as follows:—Select the most rotten specimen of the three, and remove a small piece of the worst portion with the blade of a knife, which has just been sterilized by passing it several times to and fro through the hottest part of a Bunsen flame. Allow this piece to fall on the surface of some nutrient gelatine in a Petrie dish; replace the cover, and set it aside for a few days. So soon as signs of active growth are visible in the contents of the dish, examine them daily in a good light; endeavour to distinguish how many kinds of mould develop from the piece of decayed fruit.

(7) To prove that the discolouration of cheese is caused by living organisms, remove a tiny piece of the blue or green portion of a well ripened cheese (Stilton, Gorgonzola, Camembert, etc.), by means of a knitting needle or penknife, either of which must be sterilized before use, by passing them to and fro through the hottest part of a Bunsen flame. Sprinkle fragments of the cheese, like minute seeds, over the surface of some gelatine in a Petrie dish. Set the dish aside for two or three days; then examine it daily, and count the number of different varieties of moulds which develop upon the gelatine.

NOTE.—The most usual cause of the numerous kinds of decomposition which occur in foods is due to the growth and activity of yeasts, moulds and bacteria, whose presence or whose products render the food unwholesome and generally unpalatable, and whose inroads can only be prevented or controlled by the employment of scrupulous and vigilant cleanliness. Micro-organisms are present in the air, water, and soil, as well as in every part, external or internal, of animal and vegetable substances. By far the greater number of these omnipresent micro-organisms are beneficial and beneficent in their action, but a certain proportion of them are injurious to life, while other varieties render food unwholesome.

Fortunately the putrefactive changes thus caused are, in the majority of cases, associated with the development of unpleasant gases, odours or flavours, which draw attention to their presence and lead to the rejection of the substances in which they have taken place.

A very important exception to this rule of obvious offensiveness is found in the case of *ptomaines*, certain substances which may be found during the decomposition of nitrogenous material. They belong to a class of organic chemical compounds related to ammonia. They may form in meat, fish, milk or cheese, though none of these may show obvious signs of putrefaction or other changes. Cooking is powerless to alter the poisonous effect of these deadly *ptomaines*, so that it is often impossible to foresee the danger which results from the consumption of them.

Scrupulous cleanliness in every stage of handling the food is the best precaution against their formation. In almost every recorded outbreak of ptomaine poisoning, for instance, the infected food had been stored where it was exposed to emanations from drains. Many cases of such poisoning with fatal results are on record from the use of meat (especially in pies), of fish, milk, ice cream and cheese in which these complex ptomaines had developed; and, since the bacteria which produce them grow best at a high temperature, cases of such illness occur most frequently in hot weather.

It is, however, a regrettable fact that methods have been devised, and are employed by the unscrupulous, by which repulsive odours or flavours in unwholesome foods can be disguised (*e.g.*, by the use of spices with tainted sausage meat), or the results of chemical changes can be masked, so as to enable many unwholesome articles of food to be palmed off upon unsuspicious customers.

Saprophytes is the generic name given to all the myriad varieties of bacteria which live freely in the air, in water or in soil. They feed upon dead organic matter, and readily attack many kinds of human foods, especially those rich in fat or proteid matters; and though they rarely injure pure sugar, which is not favourable to their growth, they nevertheless feed upon it when in dilute solution. Few articles of food escape their attacks if moisture be present and the temperature be suitable.

Yeast plants grow very freely in dilute solutions of sugar, as well as in combinations of nitrogenous and mineral matters. Moulds develop upon almost every kind of organic material, while bacteria flourish luxuriantly in nitrogenous food-stuffs (as has been mentioned) such as meat, fish, cheese, peas or milk.

In all cases warmth, moisture, and suitable nutrition are requisite conditions to the development of these lowly forms of life. Their capacity for multiplication is so great that it is stated, on good authority, that one bacterium may be responsible for the production of seventeen millions of descendants in twenty-four hours. Yeasts grow less rapidly, but nevertheless the power of multiplication is very remarkable in both yeasts and moulds.

Most forms of bacteria, yeasts and moulds, only grow in the presence of air, but there are species of the former which develop in the absence of oxygen (*anaerobic bacteria*), so that the exclusion of air, *e.g.*, in tinned foods, does not necessarily mean the preservation of their contents from decomposition.

It must be pointed out that the spores of bacteria, like the seeds of plants, possess much greater powers of resistance to adverse conditions, and retain their vitality for much longer periods than do the parent organisms; in consequence, the spores may retain their latent vitality when the bacteria, of which they are the offspring, have been destroyed by heat or other agencies.

Under conditions favourable to their development it is believed that spores may germinate and reach maturity in from twenty to thirty minutes.

Moulds also develop from spores, which are so light that they are continually dispersed by the wind or blown about by the movements of feather brushes or dusters. They settle

down, with the other constituents of dust, upon all exposed surfaces, such as shelves and furniture. The spores germinate and send out fine threads which penetrate into and spread over the substance they attack. At first they are almost colourless, but when in due course more spores develop, the growth becomes gradually coloured.

A distinction must be made between the spores of bacteria and those of moulds. The former are comparable to seeds when kept dry; they are in a resting not a reproductive stage, freezing or boiling seem alike innocuous to their latent vitality, and activity only quickens when moisture and warmth are furnished in suitable proportions. The spores of moulds, on the contrary, more closely resemble the active growing flowers of a plant, to the roots of which the thread-like fibres (*mycelium*) of the moulds would roughly correspond.

Moulds also cause fermentative changes in food-stuffs, owing to the enzymes they secrete, thus causing "decay" in raw fruits; they can also render solid substances, such as bread, cake or jams, quite useless for food. Moulds are usually destroyed by a temperature from 65° to 100° C. (149° to 212° F.), but a better method than the application of heat is to protect food-stuffs from their inroads by storing them, carefully covered, in clean, cool, dry places. Fruits and vegetables such as oranges, lemons, tomatoes or cucumbers are well protected from the inroads of moulds by their stout skins, if these be kept dry and uninjured by cuts or bruises.

Certain forms of bacteria cause objectionable kinds of fermentation, notably so in the case of carelessly tinned fruits, consequently it is advisable to cook all fruit slowly but thoroughly before putting it into jars or bottles.

II.—Conditions which affect the Preservation of Food.

MATERIALS: *Bread; cheese; jar of red-currant jelly; ripe grapes; raisins; apple syrup; yeast; sugar; ice; salt; cotton wool; thick, black paper.*

APPARATUS: *Slips of glass or small plate; bell-jar; test tubes; thermometer; beakers; enamelled mug or small pan; balance; wooden spoon; packing needle; retort stand; Bunsen burner.*

(*A*) *Moisture.*

(1) Cut two fingers of bread (*a*) and (*b*), moisten the surfaces of (*b*) with water. Lay both pieces side by side on a small plate or glass slip, but not in contact with each other. Cover the plate with a bell-jar and set it aside for a week, then examine the appearance of the specimens.

Repeat the experiment, but substitute pieces of cheese for the fingers of bread.

(2) Pull two or three ripe grapes from their stalks and lay them on a small plate with the same number of raisins; cut one of the raisins in two pieces. Cover the fruit and proceed as directed in (1).

Compare the results of the presence of moisture in the grapes with the unchanged condition of the dried raisins, even where a cut surface is exposed to the air.

(*B*) *Light.*

Half fill two large test tubes (*a*) and (*b*) with a mixture of syrup and water, and add to each three or four drops of a watery solution of yeast. Plug the mouth of each test tube with cotton wool and enclose (*b*) in a case of thick, black paper. Set both tubes aside for a week at a temperature of about 20° C. (68° F.), then determine whether the growth of the yeast plants has been more luxuriant in (*a*) or in (*b*).

(*C*) *Temperature.*

Label five test tubes, (*a*), (*b*), (*c*), (*d*), and (*e*); half fill each with cold water. Cut an apple into small pieces and place some of these in each tube. Plug all the five tubes with cotton wool and treat them as follows:—

Set (*a*) aside in a warm place, 20° C. (68° F.).

Prepare a freezing mixture as follows:—Chip some ice into fragments with a packing needle, mix these quickly with about half the quantity of pounded salt and transfer the mixture to a large beaker, stood if possible on a piece of cork or wood (non-conductors). Surround the beaker with

cotton-wadding or folds of flannel, and immerse (*b*) in its contents. Leave in position until the next day, then remove (*b*) and set it aside with (*a*).

Place (*c*), (*d*), and (*e*) in a large beaker half full of cold water supported over a Bunsen burner. Insert a thermometer, which should be kept in position by passing one end through one of the upper rings of the retort stand. Watch the temperature of the water as it rises; when it reaches 94° C. (201° F.) remove (*c*). When the water boils, immediately remove (*d*); leave (*e*) in the boiling water for at least half an hour.

Set (*c*), (*d*), and (*e*) aside with (*a*) and (*b*) for a week, then examine the condition of the contents of each tube. Can you safely draw any conclusion as to the influence of temperature upon the wholesome preservation of food-stuffs?

(*D*) *Suitable nutrition or pabulum.*

Take a few grapes or currants; weigh them and place them in an enamelled mug or small pan and cook over a Bunsen burner until the juice flows freely from the fruit, which should meanwhile be crushed with a wooden spoon. Then strain the juice through butter muslin into a clean vessel and add about one-third its weight of sugar. Again heat the mixture, then pour it into a shallow basin or beaker and set it aside for a week or ten days. At the same time remove the covering from a small jar of red-currant jelly, set this aside with the prepared fruit juice, also uncovered, and compare the condition of the contents of the two vessels after a week.

NOTE.—Although all forms of decay are due to the presence of micro-organisms, nevertheless water, oxygen and warmth are, in the majority of cases, essential to their development. Professor Conn points out that most of the bacteria which interfere with the domestic food supply grow best at temperatures varying from 20° to 35° C. (68° to 95° F.). Rapidity of growth is usually diminished at 35° C. (95° F.) and the majority are incapable of growing at temperatures between 51° and 60° C. (124° and 140° F.). On the other hand 51° C. (124° F.) is the temperature most favourable to the growth of some few species.

Bacteria require as much as 25 % of water in their foods, whereas moulds develop wherever there is a slight superficial dampness. Both therefore can grow on bread, cake or biscuits, but biscuits in tins are safe from the attacks of moulds. The tendency of food to rapid putrefaction when removed from cold storage is possibly due to the large amount of moisture which condenses upon its surface when it is brought back into warm or damp air; a condition which is generally favourable to the growth of moulds. Prudence, therefore, dictates the immediate cooking and prompt consumption of articles of food which have been transported long distances and preserved in cold storage during transit.

Cold, of sufficient intensity, effectually prevents putrefaction or inhibits its further progress if already active, meanwhile concealing the characteristic odours. These odours reassert themselves however, when the temperature of the food is raised, by cooking, for instance, and act as a danger signal. Apart from these disadvantages which constitute often unsuspected dangers, the most satisfactory means of preserving food for indefinite periods, during long journeys and in all climates is found in cold storage. The nutritive value is unimpaired, the flavour is little if at all affected, the appearance is unchanged, no unwholesome chemical preservative is added, and no risks are incurred such as are associated with tinned foods. If possible, a visit should be arranged to a Cold Storage Depôt, or even to the "cold room" of a butcher or fishmonger, in order that the pupils may see the means taken to maintain a sufficiently low temperature, to ensure ventilation and to protect food-stuffs from injury.

Unfortunately, the temperature of the domestic "refrigerator" is neither low enough nor sufficiently even to do more than temporarily arrest the growth of micro-organisms which require a high temperature for their development. Meat and fish may and often do suffer from forms of putrefaction associated with low temperature when stored in ice chests, especially if these be not kept scrupulously clean. The refrigerator must be stood in a clean, light, dry, airy place, and every part should be thoroughly scalded with hot water and soda at least once a week. No food should ever be put away warm, neither should it be allowed to come in contact with ice, for the purity of ice, on account of its sources, is often of a very dubious character.

It is advisable to impress this point by directing the students to make a culture with a few drops of the water collected from the melting of a small piece of ice; the temperature of the water should be that of the room, at least 15° C. (59° F.), before it is combined with the nutrient gelatine. The same procedure can be followed in all respects as that directed in VI. "*Water*," III. (*F*) (2), *page* 66; XVIII. "*Beverages*," I. (*A*) (7), *page* 410.

The results will be sufficiently impressive to allow of a warning being given against dropping ice into beverages. These should rather be chilled by being surrounded with a freezing mixture, never by the introduction of ice itself.

The economic advantages which follow the use of a mixture of ice and salt should be explained. Three-parts of ice to one of salt is a useful proportion to advise.

III.—Methods of Food Preservation in Common Use.

MATERIALS: *Raw meat; milk; soup or broth; green peas; ripe currants; tins of meat, sardines, fruit, vegetables and milk; butter; jam or marmalade; salt; oil; vinegar; filter paper; turmeric paper; borax; hydrochloric acid; household ammonia; salicylic acid; sulphuric acid; chloroform; cotton wool; string; butter muslin; rubber rings; cork.*

APPARATUS: *Balance; test tubes; pipette; beakers; funnel; glass rod; c.c. measure; small enamelled bowls; flask; sharp knife; spoon; retort stand; water and sand-baths; Bunsen burner.*

(*A*) Take three pieces of raw meat (*a*), (*b*) and (*c*), each to weigh about 15 grams (½ oz.). Immerse:—

(*a*) in a test tube of water;

(*b*) in a test tube of vinegar;

(*c*) in a test tube of brine, made with a saturated solution of salt and water.

Arrange (*a*) and (*b*) on a water-bath over a Bunsen burner and raise the temperature of the water in (*a*) and the vinegar in (*b*) to 60° C. (140° F.). Then set them aside with (*c*) for several hours.

Take three test tubes (*d*), (*e*) and (*f*) and transfer the meat, but not the liquids, to these test tubes. Plug the mouths of all three with cotton wool, and keep under daily observation. Does putrefaction occur in each case? Determine whether brine or vinegar delays the process most effectually.

(*B*) *Make a list of preserved foods in common use*; give reasons for the use in each case of the preservative methods employed.

The following examples will serve to suggest many other illustrations of familiar foods for which different methods of preservation are employed:—

(1) *Ham* (for example) is trebly protected from bacterial action; (*a*) it is dried, and a considerable proportion of its moisture is thus removed; (*b*) it is impregnated with products injurious to bacteria; (*c*) it is salted.

(2) *Dates*; these are protected (*a*) by drying, and (*b*) by the large proportion of sugar they contain.

(3) *Root Vegetables*, from which air is excluded by burying them in sand or in dry earth.

(4) *Apples*, which are stored in straw or sawdust, in order that all surface moisture may be absorbed and the growth of moulds inhibited.

(5) *Pickles*. Vinegar is the preservative employed in this case, which affords well nigh complete protection against bacterial action.

(6) *Rich Cakes* or *Mincemeat* are kept from fermentation or putrefaction by the antiseptic properties of the spices or alcohol (brandy) used in their preparation.

(7) *Eggs* are preserved from the air (with only qualified success) by brine, water-glass, etc. As bacteria are always present before the egg is laid, no means can be employed for this purpose which is wholly satisfactory.

NOTE.—The household preservatives employed for foods, such as *salt*, *sugar*, *vinegar*, *spices*, *herbs*, *oil* or *alcohol* are all designed either (*a*) to dry the articles by absorbing water from their tissues, (*b*) to prevent fermentation or putrefaction by rendering the conditions unfavourable for the development of moulds or bacteria, or (*c*) to exclude the air which is usually essential to their growth.

(1) Salt abstracts water by osmosis into the brine, and also removes some of the soluble organic constituents of meat and fish, which afford a congenial soil to bacteria.

(2) Sugar in excess, as in jams and jellies, inhibits the growth of moulds and bacteria even more effectually than that of yeasts; no fermentation occurs in preserves where the percentage of sugar exceeds 40 %, though moulds grow readily on their surface.

(3) *Oil*, *lard*, *butter*, *paraffin* and even *flour* act as preservatives to food, over which they are allowed to form an impervious surface layer, by excluding the access of air.

(4) *Alcohol* withdraws water from and consequently dries and hardens substances immersed in solutions of spirits, and inhibits bacterial action even more effectively than vinegar.

(5) *Desiccation*, or the withdrawal of water by drying, is a method of preservation normal to seeds; it answers better when employed to preserve fruits and vegetables than when applied to animal foods, which usually suffer considerably in digestibility, flavour and appearance. In this country meat and fish are smoked as well as dried, thus they become impregnated with *acetic acid*, *creosote* and other preservatives present in the products of the combustion of the peat, coal or wood fires, to which they are exposed for a greater or less length of time.

This treatment, however, does not suffice to destroy any parasites present in the food nor to protect the consumer from their attacks. Hence the great importance of cooking all dried animal foods before eating them.

(6) *Essential oils* and *spices* are also used as domestic preservatives, but a warning lest their pungency should mask incipient decay must not be omitted when reference is made to this method.

Bitter herbs, such as *camomile*, *hops*, or *gentian*, contain what are termed "bitter principles" of a glucoside nature, to which they probably, in part, owe their virtues as preservatives. It is also possible that these are, in a measure, due to certain volatile oils as well as to certain acids which enter into their composition.

(*C*) *Preservation of Food by Heat.*

(1) Prepare four test tubes (*a*), (*b*), (*c*) and (*d*). Fill (*a*) and (*b*) with milk, and (*c*) and (*d*) with soup or broth. Plug the mouths of (*a*) and (*c*) with cotton wool and set both tubes aside for future observation. Arrange (*b*) and (*d*) in a water-bath over a Bunsen flame, raise the temperature of the water to boiling point and maintain the temperature for twenty minutes; plug the mouths of the tubes with cotton wool directly the source of heat is removed.

Repeat the heating process after one hour, being careful to remove the plugs before exposing the test tubes to the high temperature. Then set these two tubes aside with (*a*) and (*c*) and watch any changes which take place in their contents during a fortnight. The contents of (*b*) and (*d*) should remain unchanged during the whole of this or of a longer period, if due care be exercised in heating the milk and soup, and in the subsequent immediate exclusion of all particles of dust.

(2) Place an equal quantity of green peas and ripe currants in two large test tubes, (*a*) and (*b*); fill up the tubes with water; pour a film of oil over the surface of (*a*) or plug the mouth with cotton wool.

Immerse (*b*) nearly to its neck in a vessel of boiling water over a Bunsen burner; maintain this temperature for five minutes; then, while the water is still boiling, exclude air from the contents of the tube by whichever method has been adopted in the case of (*a*).

Set both tubes aside for subsequent observation and comparison.

(3) Take two portions of raw meat (*a*) and (*b*), each weighing about 25 grams (2 ozs.). Cook (*b*) for ten minutes either by baking or boiling.

Suspend both pieces in the air by means of strings, so that no part of their surface is in contact with any other substance.

Note the length of time which elapses between the first signs of putrefaction in (*a*) and their appearance in (*b*).

(4) Repeat XVII. "A Study of Milk," I., (*J*), (*L*), *pp.* 389—392.

Note.—Bacteria and yeasts are very intractable when they are intimately mixed with solid food-stuffs and not merely adherent to exposed surfaces. It is rarely possible by domestic methods to raise the temperature of the interior portions of large joints to a sufficiently high point to ensure the destruction of such micro-organisms.

(*D*) *Preservation of Food by Sterilization and Exclusion of Air.*

Examine several specimen tins of tinned provisions—meat, sardines, fruit, vegetables and milk.

(1) The tins should show at either end and in any part of their surface, slight bulgings inward, not outward, where they have been bruised by blows or falls.

If the tops and bottoms of the tins are quite flat, or if convexities are to be found at either end or upon any part, gases of putrefaction have formed and accumulated within and the contents are therefore bad.

(2) Tap the tins with a pencil, glass rod or a finger nail. If either tin give out a hollow drum-like sound when struck, the contents are presumably bad from the same cause mentioned in (1).

(3) *Prescott and Underwood Test.* Stand a small specimen tin in an enamelled cup or pan three-fourths full of water; arrange it over a Bunsen burner and raise the water to boiling point. Maintain at this temperature for one hour, during which the ends of the tin will swell and become more or less convex; then set the tin aside for eight hours to cool. If the ends of the tins are still convex after this length of time the contents are unsound; if in good order the ends will "snap back" into slight concavities during the cooling process.

NOTE.—The tinning or bottling of foods is an extensive application of the method of food preservation by the exclusion of air.

If by any means the sterilization be not complete, or if the package be insecurely sealed so that organisms can be introduced from the external air, the process of decay will begin after a time, gases will be generated, and the vessel when opened will show the effect of the pressure of the gas within by its escape through the aperture when first made.

The poisonous alkaloidal bodies, known as *ptomaines*, resulting from the decay and change of nitrogenous materials do not develop in perfectly sterilized packages, but may develop in those which are imperfectly sterilized or in sterilized packages which are opened but not eaten for some time after exposure to the air. It is, therefore, highly important in all such cases to be assured that the packages have been thoroughly sterilized, that they are in good condition when opened, and that they are consumed without any great delay after being opened.

Considerable doubt exists as to the extent to which the natural acids of foods may corrode the inner surface of the tins and form possibly injurious metallic salts.

A wise precaution to take in the case of any form of tinned foods is to remove the whole contents from a tin immediately it is opened, and to place them in a glass, china or earthenware dish, for chemical action is more liable to occur in the presence of oxygen than when the air was entirely excluded from the previously hermetically-sealed package. This precaution must not be omitted in the case of fish preserved in oil (as sardines).

Where the additional cost can be afforded it is advisable to purchase provisions preserved in glass vessels instead of in tin, and glass or china jars should be invariably used for preserving fruits and vegetables.

A further caution should be given as to the regrettable custom occasionally practised of piercing a minute hole in "blown tins" by which the gases of putrefaction can escape; thus tinned goods which are known to be unwholesome can still be disposed of. A spot of solder, concealed by a label, covers the hole, the tins lose their tell-tale convexities and are retailed at nominal prices to unsuspecting and ignorant customers.

(*E*) *Preservation of Food by Chemical Means.*

(I.) *Borax and Boracic Acid.*

(1) *Meat.* (i.) Take about 56 to 60 grams of raw meat (2 ozs.) and mince it as finely as possible. Divide it into two portions (*a*) and (*b*). Dissolve a pinch of borax or of boracic powder in a few c.c. of warm water and mix the solution thoroughly with (*b*).

(ii.) Prepare an enamelled mug or small bowl, and line it with a square of butter muslin secured round the rim with a rubber ring. Place (*a*) within the muslin, add sufficient hot water, 75° C. (167° F.), to thoroughly cover the meat and soak it well, pressing and rubbing the mixture with a spoon. Secure the macerated mass within the butter muslin, bag-fashion, remove it from the mug or bowl and squeeze from 28 to 40 c.c. (two or three table spoonfuls) of juice from the meat into a glass beaker. Add 15 to 20 drops of strong hydrochloric acid for each 14 c.c. of meat juice.

Filter the liquid into a large test tube, dip in it a piece of turmeric paper and set this aside to dry, preferably near a stove or other warm place.

(iii.) Repeat the procedure with (*b*). When the turmeric paper used in both tests is dry, compare the colour of the two samples; that used for (*b*) should be changed to a bright cherry-red. If, however, a dirty, rusty-red colour results in both tests, too much hydrochloric acid was added to the meat juice. In this case allow a drop of household ammonia to fall on each slip of discoloured turmeric paper.

In the absence of boric (*i.e.* boracic) acid, the ammonia merely changes the rusty-red colour to brown, just as it does if applied to turmeric paper which has not been used for testing purposes. In the presence of any form of borax a dark green or greenish-black spot forms on the test paper where the drop of ammonia has been allowed to fall.

(2) *Butter.* (i.) Take about 30 grams (½ oz.) of butter and divide it into two portions (*a*) and (*b*).

Place (*a*) in a small beaker, add 30 c.c. of hot water and stand the beaker on a hot sand-bath or in a mug of hot-water until the butter is melted.

Mix the contents of the beaker very thoroughly with a teaspoon, leave this in the vessel and set it aside to cool. It will be found that the butter will adhere to the spoon as it solidifies, and can be thus conveniently removed from the beaker.

(ii.) Filter the turbid liquid which is left in the beaker into a glass c.c. measure; a sufficient quantity will be secured for testing purposes.

(iii.) Pour 5 or 6 c.c. of the filtrate into a small porcelain basin and add 5 drops of hydrochloric acid. Dip a piece of turmeric paper into the liquid and dry it near a Bunsen burner or stove. Set it aside for comparison with (*b*).

(iv.) Repeat the above procedure with (*b*) but add a small pinch of borax or of boracic acid powder to the 30 c.c. hot water before they are mixed with (*b*) as directed in (I.). In this sample the cherry-red reaction, which is characteristic of the presence of some form of borax in the fluid tested, will be given when the turmeric paper is dry. If an excess of acid has been added repeat the confirmatory test with ammonia, as directed in (1) (iii.).

NOTE.—This test can be also applied to sausage or potted meat if preservation with borax is suspected, but care must be taken in every case to macerate thoroughly the solid substance with hot water in the proportions given in (i.), and to clarify the liquid so obtained by first chilling it as thoroughly as possible and then straining it through filter paper.

(3) Repeat "THE STUDY OF MILK" (*pp.* 395—397) to detect the presence of certain preservatives. Boracic acid and borax, I. (*N*) (1) (*page* 395); or use the method just employed in (1) and (2), modified as follows:—

(i.) Prepare a dilute solution of alum by mixing about 5 or 6 grams of alum powder with 500 c.c. of water.

(ii.) Place 30 to 40 c.c. of milk in a flask with twice the quantity of alum solution and mix by very vigorous shaking, then filter, and divide the filtrate into two portions (*a*) and (*b*). Add a drop of a solution of borax or boracic acid to (*b*).

Use 4 or 5 c.c. (1 teaspoonful) of each sample for the test as directed in (2) (iii.), and compare the results obtained.

(II.) *Salicylic Acid.*

(i.) Take from 50 to 60 grams (about 2 ozs.) of jam or marmalade and divide into two portions (*a*) and (*b*). Dissolve a small pinch of salicylic acid in water and stir it into (*b*).

(ii.) Transfer (*a*) to an enamelled mug or small china bowl, and add enough warm water to liquefy the preserve, which must be well macerated with a spoon.

Arrange double butter muslin in a funnel and strain at least 56 c.c. (2 ozs.) of fluid from the mixture into a small flask, about 140 c.c. (5 ozs.) in capacity. Add 6 or 8 drops of sulphuric acid to the filtrate by means of a pipette; insert a cork, and shake the contents of the flask for two or three minutes, then pass the liquid through filter-paper into a second flask of the same capacity.

(iii.) Add about 44 c.c. ($1\frac{1}{2}$ ozs.) of chloroform to the clear filtrate, then mix the liquids, *not* by shaking (which makes an emulsion difficult to break up), but by grasping the flask by the neck and giving it a somewhat vigorous rotary motion.

(iv.) Pour the contents of the flask into a beaker and set it aside until the chloroform settles out in a layer at the bottom of the flask.

(v.) Remove this layer by means of a long pipette, if possible with no admixture of the watery solution, transfer it to a large test tube or small flask, add an equal amount

of water and a minute crystal of iron alum; then insert a cork, and shake the whole vigorously. Set it once more aside until the chloroform has again settled to the bottom. Meanwhile carry out the same procedure with (*b*).

(vi.) Compare the appearance of the contents of the two flasks. When the chloroform has, for the second time, settled to the bottom, the upper layer of liquid in (*b*) will be tinged with purple, an indication of the presence of salicylic acid.

(III.) *Formalin or Formaldehyde.*

Repeat "THE STUDY OF MILK," I. (*P.*), "*The Presence of Preservatives. Formalin*" (*page* 396).

NOTE.—This preservative is rarely used except for milk, but where its presence is suspected in solid foods, the procedure necessary to verify the suspicion is too elaborate for elementary students, as it requires special apparatus and a laboratory training; consequently no suggestions for such tests are included.

It is an unfortunate fact, emphasized repeatedly by Medical Officers of Health in their Annual Reports, that the use of preservatives in food is increasing and that their number is multiplying. The object of their use is either to retard decomposition or to enable food to be sold which has been prepared under unsatisfactory conditions, and would otherwise speedily go bad.

The addition of most chemical reagents interferes with the processes of digestion, at the same time that they retard the action of micro-organisms, and this without impairing the taste or smell of foods to which they are applied, so that their presence is not suspected.

Repeated reference has been made to the fact that the decay of foods is due to fermentative action, caused by organisms capable of reproducing their kind, and to the *enzymes* which they secrete. The process of digestion in the alimentary canal is also largely due to the action of enzymes present in the digestive secretions. The point therefore must not be overlooked that when the antiseptic substances which are added to preserve foods reach the alimentary canal, their inhibitory action will more or less continue

during the process of digestion. Consequently this broad principle may be enunciated as definitely established, *viz.*, that all substances which are capable of preserving foods have also the property, to a certain extent, of retarding the process of digestion. They are, in consequence, inadmissible for constant and unrestricted employment by those ignorant of the results they produce when consumed in unknown quantities.

In conclusion, it may be emphasized that meat in all its various forms requires more adequate inspection and control, while fish, oysters, shell-fish, ice-cream, watercress, eggs, milk and many more articles of food are often placed on the market in an unsatisfactory condition. Scientific and common-sense control should be exercised over every phase of the production, storage and distribution of food, for in spite of the sustained efforts made under the existing Food and Drugs Acts by Inspectors and others, the administrative control of food in this country leaves much to be desired in the interests of public health.

PART IV.

XXI.—PERSONAL HYGIENE. THE CARE OF THE PERSON.

The Teeth. The Skin, Hair, Nails and Special Sense Organs. Posture. Physical Exercise. Personal Habits. First Aid in Slight Accidents.

I.—The Teeth.

MATERIALS: *Specimens of teeth (sheep's, pig's or human); alplastine; sealing wax.*

APPARATUS: *Hand-glass; block of wood or cork; file.*

(*A*) Examine the different specimens of teeth supplied for the purpose. Notice:—

(1) Their varied shapes, consider in what way these are designed to promote the biting and mastication of food.

(*a*) The *Incisors*, or "cutting teeth," which present a sharp, chisel-like edge adapted to bite food. Look at your teeth in a hand-glass. How many incisors are present in the human jaw, what is their position in the mouth?

(*b*) The *Canine*, or "eye teeth." How does their shape compare with (*a*)? What is their special use? Why should they be so much more developed in carnivorous animals, such as the dog, than in man?

(*c*) The *Bicuspids*, or "false molars." Are these teeth the same length as the canine? Observe the two "cusps" on their surface separated by a groove; hence their name, "bicuspid." Look at the teeth of a child of eight; compare them with those of a child of twelve. Are these bicuspid teeth present in both jaws?

(*d*) The *Molars*, or "grinding teeth." How many of these large, strong teeth are present in the jaw of a child of 3, of 6, and of 12 years old, and in that of an adult of 25? Have these molars the same number of "cusps" in the upper and lower jaw?

Do your observations confirm the reference to their shape expressed in their technical name, "multicuspid?"

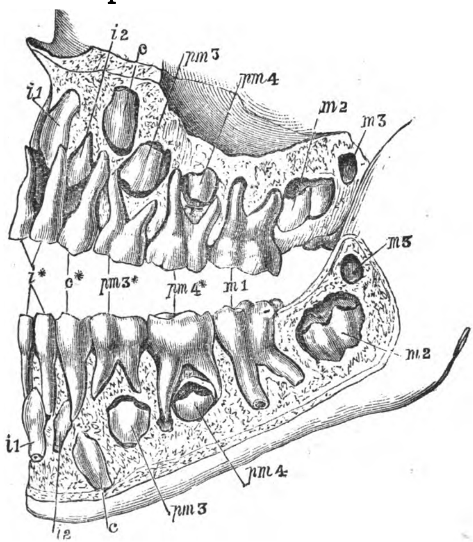


FIG. 74.—Jaw of child between 6 and 7 years old.

(*e*) Make two beds of alplastine about 2 cms. (¾ inch) thick, mould them into the shape of solid horseshoes from 6 to 8 cms. (2¼ to 3 inches) in diameter, according to the size of the specimen teeth (sheep's, pig's or human). Slightly hollow or arch them in the middle, in order roughly to reproduce the shape of the interior cavity of the mouth, then arrange the teeth round these horseshoes according to their natural order in the upper and lower iaws.

Invert one horse shoe over the other. Compare their relative positions with *Fig.* 75. How does this arrangement favour mastication? Is the statement accurate that the loss of one tooth interferes with the full efficiency of two teeth in the companion jaw? (*cf. page* 265).

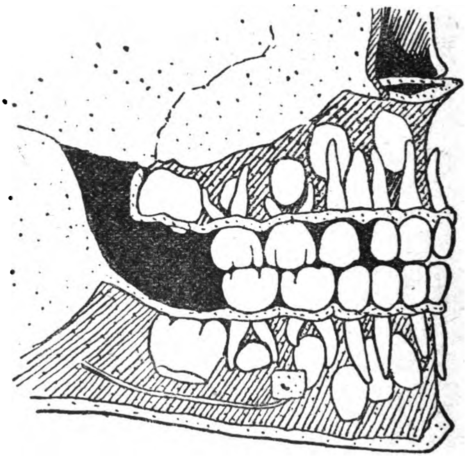


FIG. 75.—Jaw of child between 5 and 6 years old.

NOTE.—The kinds and arrangement of the teeth are usually expressed by a "Dental Formula," in which the numerators indicate those in the upper and the denominators those in the lower jaw. This formula necessarily varies according to the age of the individual, as mankind is provided with two sets of teeth which make their appearance at different periods of life, though the germs of all are present in the jaws before birth, and begin to calcify at an early age (*see Fig.* 74, where the temporary teeth are distinguished by an asterisk).

The first set, all of which usually appear between the 7th and 24th months, are called the *temporary*, *deciduous* or *milk teeth*; the second set, of which the first erupts in the sixth year and the last about the twenty-fourth, are described as permanent, because with proper care they should last throughout life.

The dental formula may be represented as follows:—

TEMPORARY TEETH.

	Molars.	Canine.	Incisors.	Incisors.	Canine.	Molars.	
Upper Jaw	2	1	2	2	1	2	Total=20
Lower Jaw	2	1	2	2	1	2	

PERMANENT TEETH.

	Molars.	Bicuspids or Pre-molars.	Canine.	Incisors.	Incisors.	Canine.	Bicuspids or Pre-molars.	Molars.	
Upper Jaw	3	2	1	2	2	1	2	3	Total=32
Lower Jaw	3	2	1	2	2	1	2	3	

The usual age at which the different teeth are "cut" should be brought before older pupils, because few people realise that the large, strong molars (*Fig.* 74 *m1*), known as "the sixth year molars," are permanent teeth, with the result that they are neglected, allowed to decay and frequently extracted prematurely, to the permanent loss of the individual. Delay in the eruption of teeth in infancy is usually a sign of insufficient nutrition, and should receive prompt attention.

The teeth in the upper jaw form a larger arch than those in the lower jaw, so that they should slightly overlap those of the lower jaw both in front and at the sides. In consequence also of the greater width of the upper central incisors, the two sets do not quite correspond to each other when the mouth is closed. For instance, the canine tooth of the upper jaw rests partly on the canine of the lower jaw and partly on the first biscupid or pre-molar, but owing mainly to the smaller size of the molars in the upper jaw, the two series terminate almost at the same point behind.

The first four molars (6th year), are the largest teeth in the head. The third series of four molars are usually called the "wisdom teeth" from their late appearance; their crowns are large, but their roots are generally single, short, conical and slightly curved (*Fig.* 16).

(2) Observe the different parts of which a tooth is composed:—

(*a*) The *Crown* or portion above the gum.

(*b*) The *Neck*, a more or less constricted part, which divides the crown from the root; it is about level with the surface of the gum.

(*c*) The *Root*; *i.e.*, the part usually buried in the gum. Find the hole at the tip of the root through which the nerve enters; this can be usually best seen in one of the fangs of a molar tooth.

(3) Firmly attach a tooth with sealing-wax to a cork or block of wood. It is advisable to make a bed of the hot wax and lay the tooth lengthwise in this. Then make a vertical section of the specimen by grinding away the exposed longitudinal half of the tooth with a file. It will then be possible to distinguish:—

(*a*) The *Pulp cavity*, which communicates with the hole in the tip of the root, through which the nerve and blood-vessel enter the tooth.

(*b*) The *Dentine* or ivory-like substance of which most of the tooth is made up.

(*c*) The *Enamel*, which covers the crown; notice how extremely hard this substance is.

(*d*) The *Cement*, which covers the root. This is virtually bone in structure and composition.

(4) Repeat (3), but place the tooth in the position it normally occupies in the jaw and make a horizontal section for purposes of comparison.

NOTE.—Teeth should be washed in strong, hot soda-water before examination. Almost any kind of teeth will serve for the purpose, especially those of the pig, though it is often possible to obtain human teeth; indeed for (1), (*a*) and (*b*) artificial human teeth answer the purpose admirably.

The shape of the cavity revealed in the interior of the tooth by the vertical section made in (3) corresponds somewhat with that of the tooth; it opens by a minute orifice at

the extremity of each fang, and contains the *dental pulp*, a soft, highly vascular and sensitive substance, exposure of which causes pain and tenderness.

The solid portion of the tooth consists of three distinct substances, (1) the *dentine*, a modification of osseous tissue, which forms the principal mass of a tooth and is composed (according to Berzelius and Bibra) of 28 parts of animal and 72 of earthy matters; the former is resolvable by boiling into gelatin, the latter consists chiefly of phosphate and carbonate of lime and phosphate of magnesia. (2) The *enamel*, which forms a thin crust over the exposed part of the crown, consists of 96·5% of mineral salts and 3·5% of animal matter. (3) The *cement* or *crusta petrosa*, which resembles bone; it increases in thickness with age.

The symmetrical development or regular eruption of teeth may be affected by poor nutrition, by constitutional or congenital disturbances, by the habits of mouth-breathing, thumb-sucking, or by habitual use of "comforters."

It may be assumed that bacteria are the cause of dental *caries* (or decay); the character of the diet seems to be of small moment, cleanliness of the mouth and regular intervals between taking food, on the contrary, are of the first importance. More than one hundred varieties of micro-organisms which flourish in the mouth have been identified, of which some produce acids by fermenting food particles in the mouth. These acids dissolve away the lime salts of the enamel and the dentine, but so long as the former is intact the underlying dentine, which is much more soluble, is safe.

It is of the greatest importance therefore to detect the first signs of decay in the enamel, and by the adoption of preventive measures to protect the dentine from being attacked.

Tartar is a hard deposit formed by a mixture of the lime salts precipitated from the saliva, its presence favours the injurious activity of bacteria. If necessary, it should be removed by a dentist, though the regular and frequent use of a tooth-brush with powder and lukewarm water should suffice to prevent its formation.

Children should be taught to use a tooth-brush if possible night and morning, certainly at night, with preferably slightly warm-water and precipitated chalk. If there be considerable tendency to dental decay, the brush should be drawn across a piece of Brook's soap before it is dipped

in the powder, which adds a slight amount of grittiness to the powder and assists in the removal of the saliva, microscopic particles of food and micro-organisms from the teeth and their interstices. A soft tooth brush should be used regularly so soon as a young child has two teeth side by side.

The following points in connection with care of the teeth can be scarcely too strongly impressed upon young people:—

(1) That white, even, healthy teeth are a great personal beauty.

(2) That good teeth are essential to good digestion, good blood and good intellectual capacity:—

(*a*) Because food cannot be digested unless masticated; an impossible process when teeth are tender, decayed or extracted.

(*b*) Because dental decay consists of the products of micro-organisms, a form of poisonous pus, which undermines health when constantly swallowed, or which forms a painful or even dangerous abscess when pent up and forced to work its own way to the surface.

(3) That regular and suitable cleaning of the teeth is a mark of self-respect and a duty to others, to whom foul breath and dirty teeth are an offence. That mouth washes or tooth-pastes or soaps are insufficient and ineffectual to remove the alkaline, viscid saliva and its contained micro-organisms, for which purpose the slight grittiness of powder is essential.

(4) That ice cold or very hot drinks or foods should be equally eschewed, as experiments show that the enamel of the teeth is liable to crack from exposure to extremes of temperature. That sweets between meals are an undoubted source of acidity destructive to the teeth, while anything but most moderate smoking, and that after maturity (25), is injurious to the enamel.

(5) That to eat hard crusts of bread, biscuits or other food-materials requiring mastication is a double duty and an economy; (*a*) it exercises the jaws and the teeth and helps to cleanse the mouth; (*b*) more nutriment is extracted from food when well masticated, therefore children must be trained to chew, not to reject the crust of bread, crisp biscuits or nuts. This remark does not apply to *cracking* the shells of nuts with the teeth, which is liable to injure the enamel.

(6) Decay in the first or temporary teeth is as serious as in the permanent ones, for it spreads to the second set of teeth and infects them even before they are erupted; it interferes with the shape of the jaw by leading to their premature loss, and it seriously damages the health of the child by the pain caused, the pus swallowed and the imperfect mastication which results. Explain that, as the crown of the permanent tooth grows, the fang of the temporary tooth is absorbed, so that finally its crown only remains; this is shed or removed and the permanent tooth takes its place.

Dental enamel has no power of self-repair similar to that possessed, for instance, by the cells which form the skin; once damaged or destroyed the tooth is left defenceless, unless assisted by artificial means.

II.—The Skin.

MATERIALS: *Towel; soap; permanganate of soda or potash solution; rubber finger-stall; cotton wadding; bladder; water; hand lens.*

APPARATUS: *Glass jar; piece of clear glass.*

(*A*) Repeat "THE SKIN, ITS STRUCTURE, FUNCTIONS AND EXCRETIONS," (*pp.* 197-202), (*A*) (1), (*B*) (1) (2) (3), (E), (*F*) (1) (2) and (*H*), and then answer the following questions from the information thus obtained:—

(1) For what purposes of protection to the body is the *epidermis* tough and insensitive, the *dermis* tender and very sensitive?

(2) What part is played by the *sebaceous glands* in maintaining the healthy condition of the epidermis, does this contribute to its protective functions?

(3) Give examples of the five forms in which heat is given off from the skin (*a*) Radiation, (*b*) Conduction, (*c*) Convection, (*d*) Perspiration, (*e*) Evaporation. Which of these is the most important? (*see* "CLEANLINESS," I., *infra*).

(4) How can you prove the fact that the surface cells of the epidermis are removed from the body by friction, or that their formation is stimulated by friction or pressure?

(5) Which organs in the body would have to take on some of the functions of the skin were a large portion injured by burning or by extensive disease?

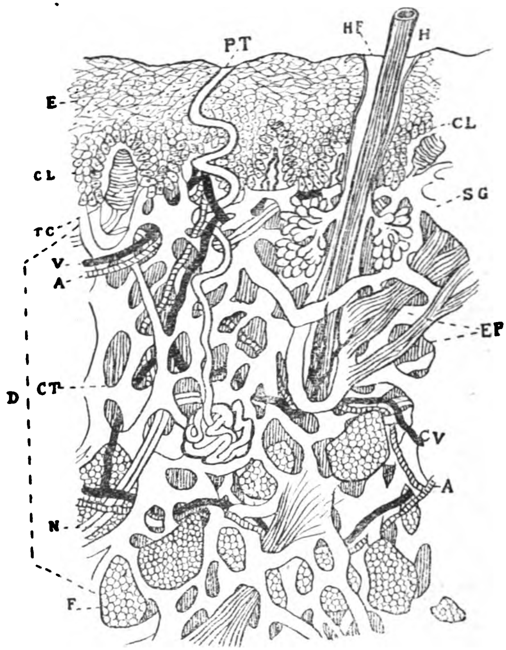


FIG. 76.

E.—Epidermis.	C.T.—Connective tissue.
D.—Dermis.	F.—Adipose tissue.
A.—Artery.	H.F.—Hair follicle.
V.—Vein.	P.T.—Perspiratory tube and gland.
N.—Nerve.	S.G.—Sebaceous gland.
C.L.—Colour layer.	E.P.—Erector pilae muscle.
T.C.—Tactile corpuscle.	H.—Hair.

(6) Does the clammy feeling of the skin after it has perspired freely throw any light upon the chemical composition of perspiration?

NOTE.—The answers to these questions will afford the necessary opening for emphasizing the chief reasons for judicious care of the skin; they are also framed to elucidate the various functions it fulfils:—(*a*) Protective, (*b*) Sensory, (*c*) Excretory, (*d*) Heat regulating, (*e*) Secretory.

Its power to absorb either gases, fluids or medicaments such as ointments is too questionable to be given much prominence.

(1) The beauty of a healthy skin should be appreciated by observations. Point out the advantages of the insensitive epidermis which is exposed to constant pressure, contact with sharp surfaces, etc., and the equal advantages of the sensitive dermis, which gives warning of the penetration into the deeper structure of possible causes of injury.

(2) Emphasize the lubricating properties of the secretion of the sebaceous glands (*p.* 201), which make the hair glossy and the skin supple. When the skin is chapped or "cracked" by failure of this secretion its protective power is reduced, dirt can enter these cracks and may cause festering sores (*see* XXIII.—"*Cleanliness*," *infra*), or micro-organisms can gain access to the tissues and lead to extensive disease of the skin, such as impetigo, ringworm, scabies, eczema or erysipelas.

(3) Heat is given off from the skin (*a*) by radiation in all directions; (*b*) by conduction from contact with objects colder than the body; (*c*) the air is warmed by passing over the body (convection); (*d*) perspiration is itself a warm fluid, consequently its excretion removes so much heat from the body; (*e*) there is also the more or less rapid *evaporation* of this perspiration from the surface of the skin.

(4) In addition to the observations made in experiment (*H*) (*page* 202), pupils may be reminded of the white powdery substance scattered over the inside of dark stockings or socks when taken off after some hours wear, of the "scurf" present in carelessly kept heads, or of the dried skin which peels off a dry blister or a corn, etc.

Recall *Note* (*page* 204), in reference to the close relation which exists between the skin and the kidneys. One danger associated with an extensive superficial burn arises from the severe tax thus thrown upon the excretory powers of other organs. This question is designed to allow reference to be made, in the case of older pupils, to the marvellous correlation which exists between the secretory and excretory functions of practically all the systems of the body, except the circulatory (which is however possessed of powers of compensatory self-adjustment), thereby constituting a physiological balance of great stability. For example, the output of water by the kidneys, skin, lungs or intestine respectively varies inversely as the output of water by one or other of the remaining channels.

(5) Professor Halliburton's analysis of sweat is as follows:—

Water	98·88 per cent.
Solids	1·12 ,,
Salts	0·57 ,,
Sodium Chloride (common salt) ..	0·22 to 0·33 per cent.
Other Salts	0·18 per cent.
Fats	0·41 ,,
Epithelium	0·17 ,,
Urea	0·08 ,,

The reaction is usually acid, but it becomes alkaline or even neutral in profuse sweating, and it has a peculiar odour which characterises garments it has impregnated.

One cause for the "clammy" sensation to which reference has been made is found in the composition of perspiration. It is well known that saline solutions vaporize less readily than water, so that the persistence of the moisture of perspiration, which forms a wet film over the skin, may be attributed to the presence of various salts in chemical combination with water. "Clamminess" is also, of course, a matter of perspiration soaked cotton or linen garments.

III.—The Hair and Nails.

APPARATUS: *Nail scissors.*

(*A*) *The Hair.*

The hair and nails are both appendages of the skin, of which they are modified outgrowths. Teaching on their growth and structure should be directed chiefly to the following points, and should be illustrated by good diagrams, or, in the case of older pupils, with the aid of the microscope:—

(1) Extract a hair from the head, and draw it down between the fingers from the point to the root. Reverse the movement. Is any difference noticeable to the sensation of touch?

(2) Hold the hair in the middle and work it between your finger and thumb; repeat this two or three times. Observe that one end invariably moves towards the thumb, while the other moves away.

Examine this further end; probably a tiny enlargement will be evident to sight or touch; this is the *root* of the hair, which, when growing on the head, is enclosed in a socket called the *hair follicle*, formed by an inversion of the skin.

(3) Consider the uses of hair. Enumerate as many as you can. (*cf.* (*A*) (1) and (4), *pp.* 217, 218.)

Hold the back of the hand horizontally against a good light; compare the soft downy hairs which become visible, with the stronger growth on the legs, arms and head. Do all hairs on the body grow in the same direction? What parts of the human body are covered with hair? Is its growth of equal luxuriance in all these.

NOTE.—The substance of the hair consists of three different layers of cells, (*a*) a *fibrous layer* largely formed of flattened cells which constitutes the main bulk of the hair; (*b*) a *central portion*, consisting of nearly spherical cells sometimes called the pith; (*c*) an *outer layer* formed of flat cells which overlap one another like tiles on a roof. This formation accounts for the characteristic movements demonstrated in (2); these are invariably the same, and enable the root end of a hair to be detected with absolute certainty. The property of "matting" or felting seen in "tangled" hair is due to the same tile-like scales on the exterior of each hair.

Peabody suggests the following illustration of the way hairs are placed in the epidermis. Take a large pin and a small piece of very thin rubber sheeting or oiled silk; push the head of the pin diagonally against the rubber or silk "in such a way as to form a deep pit without breaking the surface. The rubber or silk represents the epidermis and the depression would answer to the hair follicle or pit from which projects in a diagonal direction the shaft of the hair (pin)." The roots of hairs are buried in the fatty layer of the skin.

Very straight hair is circular in a cross section (Japanese or Chinese); when oval, it is more or less crisp and curly (Europeans).

The hair is a great beauty, and stress should be laid upon its careful keeping. The use of the sebaceous glands must be mentioned, also the fact that this natural oil is distributed down and amongst the hair by daily brushing and combing.

The loss of the hair follows decay of the hair follicles or from moulds growing in the roots. The appearance of the hair is a good index to the state of nutrition. Long, luxuriant, glossy hair in childhood indicates good health; when the hair is thin, dry, short, irregular in length, broken and dull, nutrition is poor.

Hair keeps the head warm, yet at the same time shields it from the excessive heat of the sun's rays, and also protects it from injury in the case of falls or blows.

Impress the futility of the patent hair-restorers so freely advertised in the press, as well as the inaccuracy of the common statement that "singeing" is a necessary adjunct to the cutting of hair, to "close the cut ends." Hairs are *solid*, not tubular, in construction; and no loss of nutritive principles follows the removal of dry, split ends.

Advise that the hair of girl children should be kept short until 14 or 15 years of age; the free access of air to the roots promotes its subsequent luxuriant growth, while when the hair is short the scalp can be more easily kept clean. Point out that *ringworm* and *pediculi* (lice) are both common in heads where scrupulous care is not constantly exercised to preserve cleanly conditions; they constitute conditions hard to eradicate, are a source of expense from the necessity for medical superintendence to ensure their removal and seriously interrupt education, as children who suffer from either form of disease are infectious and should be excluded from association with others.

Add a caution against the promiscuous wearing or trying on hats or caps at school, in shops, or elsewhere, on account of the liability to contract either form of infection by such means.

(B) *The Nails.*

Find out as much as possible of the structure and function of the nails by careful examination of one of the fingers. Observe :—

(1) The horny structure, and the *lunula* or pale crescent at the base of each nail.

(2) The transparent substance of which the nail is formed. This is easily demonstrated by exercising slight pressure upon the outer edge of a finger nail and observing the change of colour which takes place when the blood is

excluded from or flows freely in the dermis beneath. The fact that the blood supply is not evenly distributed under the nail explains the whitish appearance where the bed of the nail is less vascular.

(3) The fact that a nail rests on a bed of soft flesh and is surrounded on three sides by epidermis which overlaps at the base. Demonstrate this fact by gently pushing back the skin round one nail.

(4) Shave off the edge of a nail, feel the horny consistency of the parings. From your observations would you say that the nails are outgrowths of the epidermis or of the dermis (*page* 202)?

(5) As a result of your observations and of your knowledge of the functions and characteristics of the fingers and toes give reasons for the positions of the nails, for their mode of growth, and for the care they should receive.

FIG. 77.

NOTE.—The nails are outgrowths of the epidermis, being actually thickenings of the horny surface layer known as the *stratum lucidum*. Each nail lies in a depression called its *bed*, the posterior part, which is overlapped by epidermis, being called the *nail groove*. Instead of being raised in papillae as elsewhere, the dermis beneath the nails is arranged in very vascular longitudinal ridges, with the exception of the pale crescent-shaped lunulae. When ill-kept, the epidermis tends to encroach too far over the lunulae and to adhere to the sides of the nails, consequently as the nail is pushed up from below by the natural process of growth this skin becomes tense, often causes pain, is broken or gives way under the strain and forms the ragged "hangnails" or "agnails." These not only disfigure the nails but offer little openings through which dirt may enter, the results of which may be a temporary sore, or a gathering, or a serious attack of blood-poisoning.

The epidermis should be gently pressed back all round the nails, more especially at the base, two or three times a week, a piece of wood or bone of a suitable shape being used for the purpose. Take care that the hands have just been washed in warm water so that the skin is soft and pliable.

The chief function of the nails is to protect the sensitive finger tips and the toes from injury and pressure.

Demonstrate the right method of cutting the nails. Those of the fingers and thumbs should be cut to correspond with the shape of the finger ends, somewhat curved or crescent-shaped; they should project just beyond the fleshy ends of the fingers to protect the sensitive tips, which if left unprotected by the nails will be rendered insensitive and thus less useful for delicate art or craft-work by an over-growth of thick skin. If the nails grow too long they render the fingers more or less useless, are liable to be broken or torn and accumulate undesirable dirt. ("*Cleanliness*," *vide infra*). Speak severely on the dirty habit of biting nails, which deforms and disfigures the hands, and leads to the swallowing of much undesirable organic dirt.

Toe-nails must not be cut to an oval shape nor too short, they must be cut *straight across*, otherwise they are liable to "grow in," or, if this very painful trouble be averted, hardened skin forms at the sides of the nails which causes much discomfort and interferes with comfort in walking or standing.

Where the tendency to "ingrowing" toe-nails is strong, it may be controlled by cutting a V shaped nick in the middle of each nail; as this closes in the natural process of growth the nail is slightly contracted towards the centre and its edges are thus drawn from the sides. The shape of shoes or boots bears very directly upon the hygiene of toe-nails.

The condition of the nails is often an index to the nutrition of the individual as well as to his breeding. Cracked, split, dull, thick, bitten, ill-kept, dirty nails indicate different forms of ill-health, organic or functional, carelessness, and a want of attention to the decencies and conventions of life. Well-shaped polished, clean nails are an index of good manners as well as of good health.

IV.—Care of the Special Sense Organs.

MATERIALS: *Specimens of printed matter; perforated cardboard; sheets of white cardboard; dark linen; red and green cotton or wool; green or black unglazed paper; needles; candle; tapers; alplastine; sharp penknife; measuring ruler; large mirror.*

APPARATUS: *Bunsen burner.*

(*A*) *The Eyes.*

Open the page of specimen types (*p.* 289) and carefully carry out the following directions.

(1) Read the passage No. 11, sitting:—

(*a*) With your back to the window.

(*b*) With your face to the window.

(*c*) With your back to the window, but with your face to a large mirror or a white wall.

(*d*) In the same position, but with the mirror or wall covered with a large piece of dark linen or other covering.

(2) Write a few words from dictation:—

(*a*) With your back to the window.

(*b*) With your face to the window.

(*c*) With your right-side towards the window.

(*d*) With your left-side towards the window.

In which position is the print most easily seen or the least shadow thrown upon the paper?

Repeat the whole series of observations with the object of arriving at a definite conclusion upon these points.

(3) Examine the specimens of printed matter supplied and classify them according to your conception of what constitutes a good specimen of type, paper and arrangement of matter.

(4) (*a*) Take a small sheet of perforated cardboard and strands of red and green cotton or wool threaded through needles. Cover the desk or table with a piece of unglazed green or black paper and work the following series of cross-stitches on the cardboard (i.) with red thread or wool, (ii.) with green.

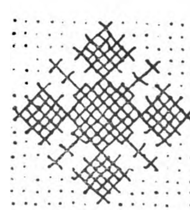


FIG. 78.

(*b*) Remove the dark paper and substitute white. Repeat (*a*). Do you find any difference in the ease with which you make the stitches in (*a*) and (*b*); does the red or the green wool prove the less dazzling to the eyes?

NOTE.—The following experiments are included in order to demonstrate more closely the reasons for the observations made in (1) and (2), and for the cautions given upon position in regard to light when using the eyes, which often prove irksome to and are disregarded by children.

While performing these experiments the individual students should be, so far as possible, isolated the one from the other; it is advantageous to darken the room.

(5) *Measurement of Illumination.* Take a large piece of white cardboard about 46 × 46 cms. (18 × 18 ins.). Arrange it as a screen in front of you on the table at a distance of about 46 cms. (18 ins.). Support an ordinary 12 inch (30·50 cms.) ruler in a perpendicular position with alplastine at a distance of 5 cms. (2 ins.) from the screen. Then light the candle and place it 30·50 cms. (12 ins.) from the screen in such a position as to throw the shadow of the ruler on the screen. What is the character of the shadow cast by the ruler?

Test the illuminating power of other lights, Bunsen burners, candles, tapers, matches, by moving them to such a distance from the screen that the shadows thrown by the ruler appear side by side equal in size and equally dark.

(N.B.—The heights of the different lights from the table must be the same.)

How do your observations assist you to determine the various illuminating powers of the different lights?

(6) *Cause of Shadows.*—Umbra and Penumbra.

(*a*) Hold the ruler *vertically* between the candle and the cardboard screen at such a distance as to throw a dense shadow.

(*b*) Retain the same relative positions of the candle, ruler, and screen, but this time hold the ruler horizontally.

What effect has the change of position upon the shadow cast by the ruler?

(*c*) Repeat (*b*), but slip a card with a circular hole in it, about 2 cms. (¾ in.) in diameter, between the candle and the ruler.

How do you account for this further difference in the shadow produced?

NOTE.—It is of course common knowledge that different sources of light have different illuminating properties, of which the relative intensities can be measured by means of a *photometer*, an apparatus somewhat roughly reproduced in (5). By altering the positions of the candles, or tapers, until the intensity of the shadows thrown are absolutely the same in each case, and then by measuring the exact distance of each source of light from the screen, the illuminating power of each can be estimated. The intensities of the various lights will be found to be directly proportional to the squares of their distances from the shadows, *e.g.*, if a candle is three times as far from the screen as a taper, and the shadow it throws is of equal intensity, its illuminating power is nine times as great. Light travels in a straight line, therefore if an opaque body be placed in a beam of light a dark space or shadow appears behind it, of which the nature depends upon the size of the body from which the light proceeds. If this be as large as the flat face of a gas jet, the shadow consists of two portions, the inner part on which no rays of light fall at all, and an outer zone which gets more or less illuminated by the source of light. The former is called the *umbra*, the latter the *penumbra*. The larger the source of light the broader is the penumbra at any given distance from the opaque body, thus the edge of a bats-wing burner casts a more distinct shadow than its flat face. A shadow is dark and well defined when the body which casts it is near, but as this distance is increased the penumbra widens until the graduation from dark to light at its borders becomes too indefinite for any boundary line to be distinguished. The absence of penumbra in (6) (*c*) is explained by the concentration of the rays of light through the circular aperture.

Reference will of course be made to "*The Eye*," V. (*pp.* 228-248).

In reading, writing or working, light should be derived from one source only, and that source should be either behind

and above or to the left and slightly above. Cross lights should be avoided, and direct sunshine falling on the book or table should be tempered.

Refer to the unwise strain put upon the eyes by reading in the dusk or by flickering firelight, and by home lessons done in the evening when tired.

When the eyes are red, sore or glued together after sleep by a sticky secretion, some error of vision is the usual cause, and the symptoms can be permanently relieved only by appropriate spectacles, after the eyes have been tested by an expert. Neuralgia, sick headaches, giddiness, pain and heat in the eyes, and many other discomforts may be caused solely by astigmatism or by short-sight.

Styes on the eyelids, eruptions and inflammatory affections of the margins of the lids often owe their origin to errors in diet, though they may be, and often are, due to want of appropriate glasses. Twitching and quivering of the lids may proceed from over-work, debility or long sight. In all cases the advice of a doctor must be sought *and followed.*

(*B*) *The Ears.*

NOTE.—Reference should be made to "*The Ear,*" *pp.* 250-259, especially to I., II. and III.

With the assistance of a good papier mâché model and actual specimens of the bony labyrinth and the ossicles of the middle ear (which will demonstrate the extreme delicacy and minute size of the structure), the effect of violent blows on, or inflammatory swellings of, the delicate aural structures can be pointed out and the following facts impressed:—

(1) That at no age, and under no provocation, should the ears of a human being be "boxed," such blows may prove immediately fatal or may set up a series of results which will cause acute sufferings, deafness or death.

(2) That pain in the ear, especially if it precede or is associated with discharge from the ear must not be neglected or tampered with by rough and ready treatment, such as the introduction into the meatus of hot oil or portions of roasted onion. Medical advice must be sought at once, for, in consequence of the close proximity of the middle ear to the brain, from which it is separated only by a thin plate of bone, there is great risk of danger to life from ear trouble, in addition to that of permanent deafness. On no account must discharge be pent in or disguised by plugs of cotton wool, usually dirty and in themselves a possible source of infection, neither must these plugs of wool be

considered as panaceas for neuralgia or ear-ache; the cause and treatment must without exception be referred to a doctor.

(3) That constant head colds are a frequent source of subsequent ear trouble, because the inflammatory condition of the nasal and pharyngeal mucous-membrane spreads easily to the delicate middle ear, along the Eustachian tube which connects the two cavities.

(4) That no effort to remove foreign bodies from the ear such as insects, beads, or peas, should be made hastily, roughly or without knowledge of the right way to act; neither must a sharp instrument such as a pin, knitting-needle or hair-pin or other hard implements be used to remove accumulations of the secretion in the ear (wax); they are all liable to do harm.

(C) *The Throat and Nose.*

Note.—Refer to "*The Larynx,*" *page* 263.

Direct observation to the fact that the health of the throat and nose depend mainly upon the condition of the mucuous membrane with which they are lined.

The duties of this lining membrane are to "act as an organ of common sensation, to minister to the senses of smell and taste, to secrete a protective mucous which lubricates the surface and itself to protect the parts that lie beneath it."

An ordinary cold in the head illustrates, in its early stages, (*a*) the extreme discomfort endured when the mucous membrane is dry and swollen; (*b*) the even greater misery when the secretion is formed in excess and materially altered in character.

Care of the nose and throat demands:—

(1) Cultivation of the habit of breathing through the nose, in order that the air may be warmed and filtered before it reaches the larynx and lungs.

(2) Avoidance of catarrhal conditions of the nose and throat by attention to the general health, also by not enveloping the throat in furs or thick wrappings or high, stiff collars, which cause the skin to perspire freely and, from the rapid evaporation which follows removal of the wraps, chills the surface, and tends to congest the mucous membrane of the throat.

(3) Chronic inflammation of the throat is often ascribed to the excessive use of tobacco, while as Sir Lauder Brunton, M.D., D.Sc., F.R.S., says:—

"In drunkards there is a great tendency to chronic catarrh of the respiratory passages, the back of the throat is often red and congested. This congestion extends down to the larynx, giving rise to hoarseness and expectoration of mucous. It very frequently extends also down the smaller bronchi, so that drunkards are rarely free from some form or other of chronic bronchitis."—"*The Influence of Stimulants and Narcotics on Health.*" (*Cassell & Co.*)

V.—Posture.

MATERIALS: *Large mirror; piece of stiff card or board; rubber tubing; stamp or gummed paper; candle or taper; matches.*

APPARATUS: *Large glass bottle; c.c. measure; slip of glass; deep basin or pneumatic trough; beehive cell.*

(*A*) Stand up in the position most natural to you, if possible in front of a large mirror, and observe the following details:—

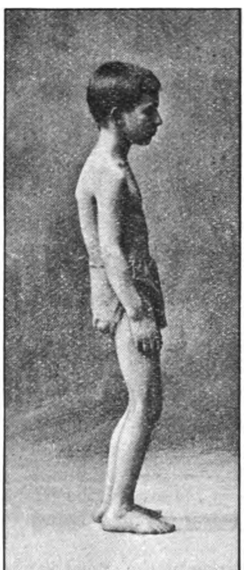


FIG 79.*

FIG. 80.*

* Reproduced by kind permission of the Royal Sanitary Institute.

(1) Is your head erect with the chin back, or does it poke forward with the chin projecting in front of the body?

(2) Are your shoulders square and upright, or are they uneven (one higher than the other) and bowed, so that the back is round instead of flat?

(3) Is the chest rounded and thrown forward, or is it flat and receding?

(4) Do you stand firmly on both feet? How are these placed in relation one to the other, side by side, one in front of the other, or is more weight thrown on the left or on the right foot?

(5) Are the knees bent or stiff? Are the muscles of the trunk and limbs braced or relaxed?

(*B*) Stand in accordance with the following directions:—Raise the chest, keep the arms and shoulders on a line with the hips, draw the chin back. Place one foot slightly in advance of the other, that is, with the heel of one foot about on a level with the instep of the other. Throw the weight chiefly on the fore parts of the feet, and straighten the knees.

How does the position into which the body now falls compare with that in which you usually stand. Observe:—

(1) The erect well poised head;
(2) The well-expanded chest and level shoulders;
(3) The upright back, slightly curved about the waistline;
(4) The flattened abdomen;
(5) The general balance of the body.

Draw a long deep breath and expire slowly. Can you do this with ease and freedom?

(*C*) Now relax the muscles, allow the head to fall forward and to one side, the shoulders to become rounded, the abdomen to project, the weight to fall chiefly on the heels or throw it more upon one leg than the other. Again inspire deeply and expire slowly.

Do you experience more or less difficulty in doing so than when standing as directed in (*B*)?

(*D*) Assume the position of "attention" required under the old system of military drill. Raise the head, throw back the shoulders as far as possible, hold the arms stiffly close to the trunk with the thumbs touching an imaginary line corresponding with the seams of a man's trousers, the feet close together and side by side. Again inspire and expire as directed in (*B*) and (*C*).

In which of the three positions is full and deep respiration most easy and effectual?

For what reason is stress laid upon the importance of habitual deep breathing?

(*E*) Observe that equilibrium is maintained by the conjoint action of the muscles anterior and posterior to the spine.

(1) Stoop forward and then straighten the back, notice the feeling of relaxation and of contraction, of elongation and of shortening in the muscles of trunk and spine.

(2) Assume different positions which call for adjustment of the equilibrium, *e.g.*, stretch one hand to grasp an object just or almost out of reach. Stand on one leg and try to pick up an object on the floor without lowering the second foot to the ground.

Watch how the muscles act in antagonism to one another in order to preserve the balance.

Look at a person who "drops asleep" in a chair. The muscles relax, gravity asserts its force, the head "nods" forward by its own weight, the passive counter-action of the extensor muscles being in abeyance.

(*F*) Enumerate as many illustrations as possible of the influence of the posture assumed in different occupations upon the symmetry and shape of the body.

NOTE.—The undeveloped legs of the tailor or jockey, the slouch of the labourer, the low right shoulder of the sempstress, the high shoulders of the designer who stands at his desk, the stoop of the growing girl, the clerk, or the literary man, the broad chest of the sailor, afford a few examples which a keen observer can multiply indefinitely.

Lead the pupils, according to their age, to trace the results of these postures upon the development and functions of the heart, lungs, digestive organs, etc., and make suited applications to the influence upon health and efficiency.

The practical importance of maintaining bodily symmetry and of avoiding habitual postures which impair health needs some emphasis to young people.

Diminished chest capacity, unsymmetrical equilibrium and relaxed muscles are symptoms associated with debility, low vitality or premature and unsuitable work (*e.g.*, spinal curvature may proceed from carrying heavy weights in early childhood as well as from bad posture when seated), they too often precede lung or nervous troubles and dyspepsia.

(*G*) Observe the influence of posture on "vital capacity."

(1) Take a large glass bottle to hold at least 3,000 c.c. (3 quarts). Pour in 560 c.c. water (1 pint) and mark the level of the water on a strip of stamp or gummed paper previously fixed the whole height of the bottle. Continue to pour in a similar quantity of water, marking the level after each addition of 560 c.c. (1 pint) until the bottle is brimful. Cover the mouth with a slip of glass, hold this firmly in position and invert the bottle under water over a beehive-cell, in a deep basin or pneumatic trough.

Deftly remove the slip of glass, and introduce one end of a 45 c.c. (18 ins.) length of rubber-tubing into the orifice of the beehive-cell. Stand in a good position, draw in as long a breath as you can, then expire slowly through the tube into the bottle. What difference do you now observe in the level of the water. Why is this? (*Cf.* "Air," (8) (9) *pp.* 41, 42).

How does this assist you to gauge your own "vital capacity?" (1 pint equals 34·65 cub. in.) (*See* "The Respiratory System," VI., *pp.* 142-3). Repeat the test with the muscles relaxed as in (*C*).

Is there any marked difference in the result?

(2) Again test the visible results of posture upon the vital capacity, or the amount of air which is habitually respired and available for the needs of the body.

Make a paper scale to measure 75 cms. (about 30 inches) in length, and lay it on the table lengthwise in front of you. Fix a piece of card or wood upright to the edge of the table so that the upper edge is level with your chin, and forms a screen between you and the table.

Arrange a taper or candle on the table in such a way that when lit the flame would be exactly on a level with your lips. Support at a distance of 50 cms. from the edge of the table, as shown by the paper scale. Stand up, light the taper or candle, draw a deep breath and expire forcibly towards the flame with the object of extinguishing it.

If unsuccessful, draw the taper or candle somewhat nearer to you and repeat the effort. The object is to find the exact distance on the scale at which you can extinguish the flame by forcible expiration.

Do not make more than three attempts consecutively, or fatigue will interfere with the fulness of your respiration and will rob the test of any value.

Compare your record with that of your companions; are the distances uniform or do they vary much?

(*H*) When you are sure of the distance at which you can extinguish the flame of a taper or candle, standing in the position which experience teaches you to assume when desirous to exert the fullest capacity of your lungs, allow yourself to relax into the attitude portrayed in *Fig.* 79, and repeat the experiment.

What difference becomes apparent as to the influence of such a posture upon the vital capacity?

NOTE.—A scale of distance must be marked on the table, an upright bar placed at the height of the pupil's chin so that he cannot lean beyond it, and the candle or taper must be arranged on a level and in a direct line with the pupil's mouth.

The average difference in the distance at which the flame can be blown out by the same individual when standing erect or when relaxed is 12 cms. (nearly 5 inches). Very decided differences will be observed in the greatest distance possible at different ages, under different conditions of nutrition or as a result of posture.

The difference is much more marked between two individuals of whom one stands well and symmetrically, the other "in a heap."

(*I*) Illustrate the different positions assumed by the feet and legs in order to support the trunk and observe in what ways they influence the balance of the body.

(1) Place both extremities evenly beneath the trunk (*Fig.* 80, *p.* 494).

(2) Throw one foot forward as in walking (*Fig.* 82, *p.* 494).

(3) Support the trunk on one leg and throw the weight of the body to that side (*Fig.* 83, *p.* 494).

Which of these positions do you consider the best for habitual use?

NOTE.—In (1) the trunk is evenly and symmetrically supported, but the position is not convenient for habitual use because it keeps both legs in muscular activity at the same time, whereas to save fatigue they are naturally used alternately. A favourite position is (3), which is to be condemned, because it produces lateral curvature of the spine and affects the development and symmetry of the organs and muscles of the whole body. It is chosen on account of the broader base it gives for the support of the body; (2) is the position of the feet which can be usefully acquired and longest retained without injury to the body when standing.

(*K*) Assume the various sitting positions illustrated in *Figs.* 84, 85, 86, 87 and 88 (*pages* 495 to 497).

In which of these is the symmetry of the body maintained, the chest well expanded, the movements of the digestive organs unimpeded, and the normal positions of the spine and pelvis retained?

NOTE.—*Fig.* 84 shows a position in which gravitation largely replaces muscular activity, and therefore it is economic in force. With support applied to the lower part of the back and below the shoulder blades, it can be maintained for a long time without general fatigue. It is, therefore, the position which should be acquired in early life as the habitual one.

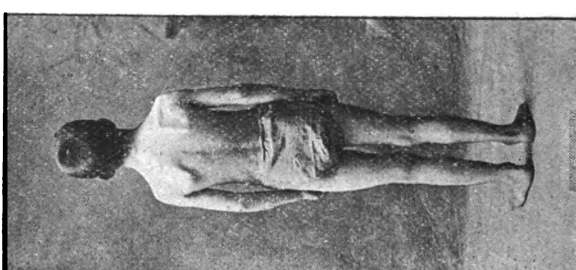


Fig. 81.*

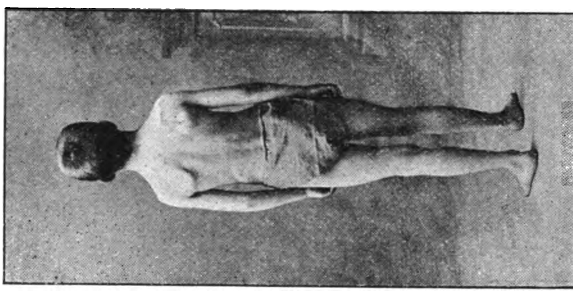


Fig. 82.*

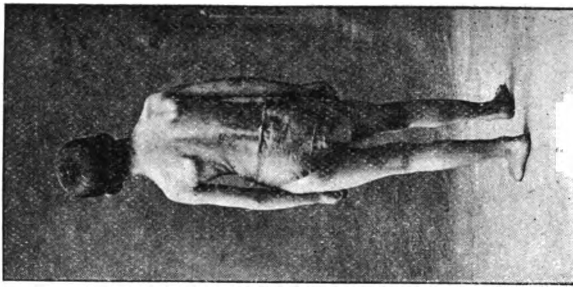


Fig. 83.*

* Reproduced by kind permission of the Royal Sanitary Institute.

The results of the positions shown in *Figs*. 85, 86 and 87 involve serious interference with thoracic development; the abdominal organs cannot function freely, and in addition to unsymmetrical and unequal muscular action, a train of other undesirable symptoms is liable to follow. Especially is this so in the case of growing girls, who are more liable to adopt and to retain this unwholesome posture than are their more actively-disposed brothers.

Fig. 88 shows a position which is exceedingly injurious if permitted to become habitual, because it places the bony segments of the spinal column in a position calculated to produce elongation of some of their connecting ligaments with shortening of others; at the same time the cartilaginous discs between the vertebrae suffer seriously from the unequal pressure, which diminishes their thickness on the shortened side. The muscles of the back are also used unequally.

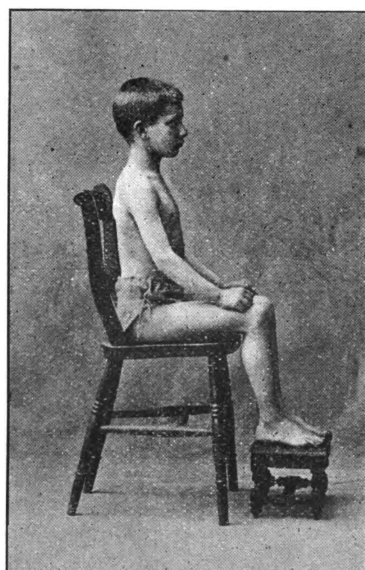


FIG. 84.*

* Reproduced by kind permission of the Royal Sanitary Institute.

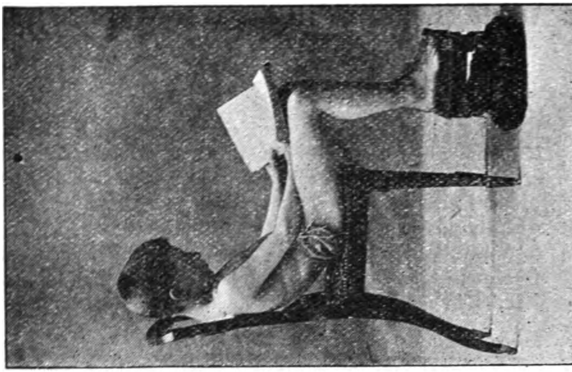


FIG. 86.*

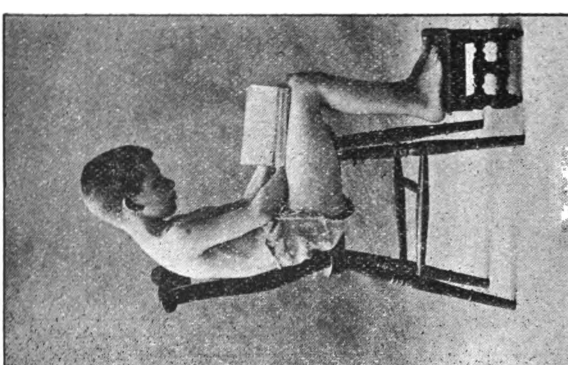


FIG. 85.*

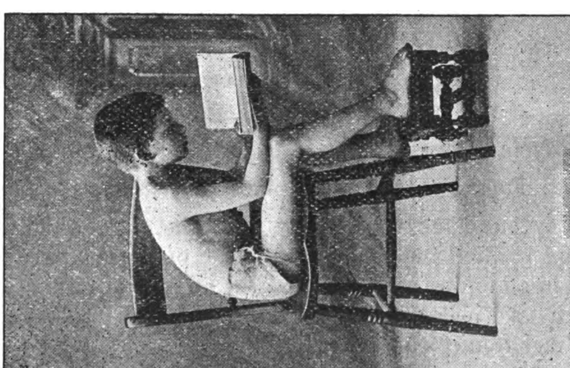


FIG. 87.*

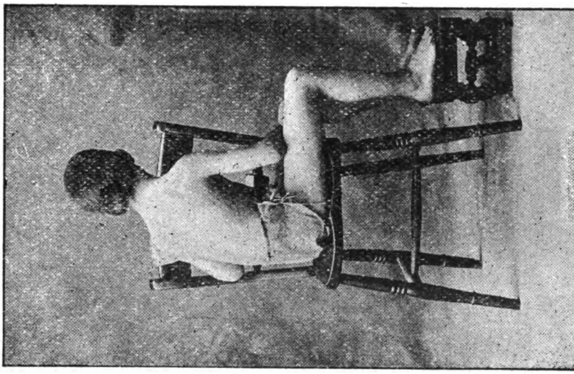


FIG. 88.*

* Reproduced by kind permission of the Royal Sanitary Institute.

Fig. 89 shows a seat and desk designed to encourage the desired sitting posture. Both can be easily adjusted to the height of different children; the supports of the back are moveable to meet individual requirements, the seat is slightly inclined backwards and is well "saddled" to give relief and comfort to young muscles, while the desk can be moved to plus, zero or minus positions according to the use to which it is to be applied.

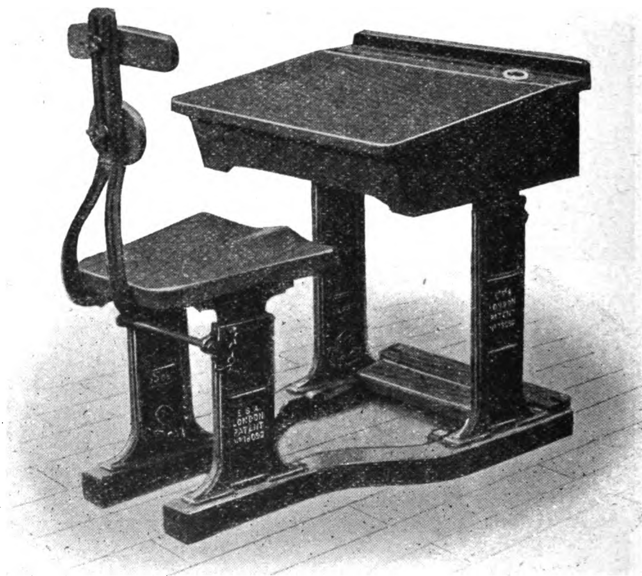


Fig. 89.*

VI.—Physical Exercise.

Materials: *Paper; pencils; needle and thread; cloth.*

(*A*) (1) Lay one hand very lightly upon the chest while in a sitting position and count the number of times it rises and falls in a minute. This will give the number of respirations which take place in that time when at rest. The record will vary from 15 to 18.

* By kind permission of the Education Supply Association.

Wipe two fingers of one hand clean and dry, and draw their tips along (*a*) the skin under the chin, (*b*) on the forehead, and (*c*) across the back of the other hand. Observe the colour of the skin touched in each case, and notice whether it feels moist, dry, hot or cool.

(2) Run briskly round the room or playground for three or four minutes.

Repeat your observations upon the respiratory movements and the condition of the skin, as rapidly as possible, after ceasing this active exercise. Is the skin more flushed or still pale ?

(3) Run quickly up and down two or three flights of stairs, again make and record your observations as in (2).

(4) Stand up ; throw both arms up straight by the side of the head, then whirl them round from back to front, at the same time jumping as high as you can from the ground. Repeat this movement six or eight times, or until breathless. (If preferred, skipping may be substituted for this exercise.) To what extent are the respiration and the skin affected ?

	At rest (1)	After running for 4 minutes (2)	After mounting stairs (3)	After jumping, with arm movements (4)
Respirations per minute				
Skin —Colour...				
„ Dry				
„ Moist				
„ Cool				
„ Hot				

Sufficient interval must be allowed between each active exercise to recover the breath and to cool down.

(5) Sit for five minutes (*a*) as motionless as you can; what natural inclination do you find it hard to restrain? (*b*) crouched in either of the positions shown in *Figs.* 86 or 87.

Then raise yourself erect in your chair and throw back your head and shoulders. Is the sensation one of relief and comfort?

(6) Stand upright, clasp the hands behind the small of the back, and twist them round each other in such a way as to draw the shoulders back. At the same time take a deep, slow breath, raise yourself on tip-toe, straighten the knees, and expire slowly as you sink the heels to the ground.

Repeat the movement several times. Notice the feelings which are associated with the stretching movement.

(7) Perform some movement which is new to you, and observe the results of repetition upon the ease with which it is performed, *e.g.*:—

(*a*) Tap the head with the right hand while describing circles in the air with the index finger of the left hand.

(*b*) Hop twice round a circle 3 metres (10 feet) in diameter without losing your balance or dropping the raised foot.

(*c*) Look at *Fig.* 41 (*page* 179) for one minute; draw it from memory and compare with the original.

(*d*) Thread a fine needle with the thread held in the reverse hand from that you usually employ for the purpose.

(*e*) Carry a pile of three books poised on your head twice the length of the room.

(*f*) Hold a heavy book at arm's length for five minutes.

Repeat these movements daily (or others, should all these be already familiar), until they are performed with perfect ease.

Note the number of repetitions necessary to attain proficiency in each exercise.

NOTE.—Muscular activity is a primary characteristic of life and is indispensable to healthy vigorous life. Its objects are:—

Recreative (as games, sports, etc.);

Physical (to fulfil the functions of life, vital, occupational, etc.);

Educational (as organized exercises and games designed to develop quick co-ordination between brain and muscle);

Corrective (as special remedial gymnastics);

Æsthetic (as dances and postures).

The immediate physical effects of active exercise are:—

(1) To raise the temperature of the body by the increased oxidation of carbon necessary to supply the energy for muscle contraction, the normal health level (36·9° C., 98·5° F.) being maintained by an increased blood supply to, and more rapid evaporation from, the skin.

(2) To quicken the respiration, (*a*) in order to meet the demand for more oxygen which results from the increased combustion in the tissues, and (*b*) to increase absorption of effete matters by the blood, and consequently to promote their more rapid and complete expulsion from the body.

(3) To increase the rapidity of the heart's action, in order (*a*) to exert a greater pressure in the blood vessels, by which a more rapid removal is effected of the products of tissue change, (*b*) to promote more rapid circulation through the lungs where the blood gives up its impure gases and absorbs oxygen.

(4) To improve the nutrition of the body by the impetus given to the lymph circulation by the muscular contractions, especially of the big trunk muscles (*page* 143).

Figs. 90, 91 and 92 will assist to a clearer comprehension of the mechanism by which the results are brought about to which reference is made in (2), (3) and (4).

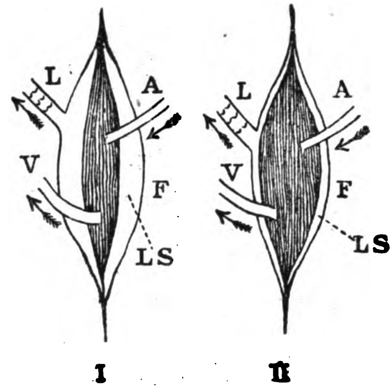


FIG. 90.*

Diagram of longitudinal sections of muscles, I in relaxation and II in contraction. F is the fibrous fascia or sheath of the muscle. L S a lymph space between the muscle and the outer layer of fascia. L is a lymphatic vessel with numerous valves, by which the lymph containing waste-products is removed. A is an artery by which fresh blood is brought to the muscle; and V is a vein by which blood is removed from it. Each time the muscle contracts, as in II, it lessens the size of the lymph space and drives the lymph onward through the lymphatics. Each time it relaxes, it tends to create a vacuum within the fascia, and thus lymph is sucked out of the muscle into the lymph space, while fresh arterial blood rushes into the muscle.

FIG. 91.*

Diagram of a transverse section of the thorax during inspiration and cardiac systole. It shows the tendency to the formation of a vacuum in the pleural and pericardial cavities.

*** Reproduced by kind permission of Sir Lauder Brunton, M.D., F.R.S., etc.**

"The effect of massage upon the muscles is to raise the blood pressure within the vessels generally, and muscular contraction, either reflex or voluntary, has a similar or greater result, and causes the blood to pour more quickly from the vessels into the heart, whilst the heart, in its turn, drives the blood on more quickly through the vessels. Muscular exertion quickens the pulse and accelerates circulation, but it is not upon the circulation alone that its effect is exerted. Respiratory movements are increased both in depth and rapidity. They not only bring more oxygen into the lungs to aerate the blood, but they have also an effect

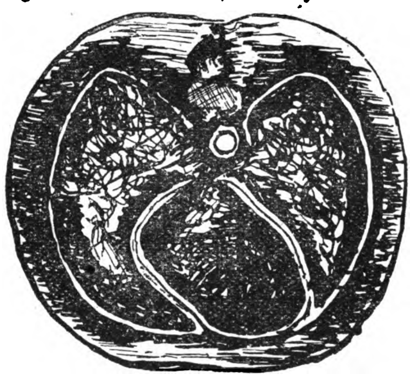


FIG. 92.*

Diagram of a transverse section of the chest during expiration and cardiac diastole, showing the pressure of the walls of the pleural and pericardial cavities against each other.

upon the heart similar to massage upon the muscles. The respiratory movements, especially when deep, help to press the blood out of the heart and to attract blood into it. The movements of the heart itself also tend to carry on a kind of self-massage. These effects were shown by my friend, Professor Kronecker, and will be understood from the accompanying figures.

"The first of these (*Fig.* 91), shows the thorax during inspiration and during contraction of the heart. In this condition there is a tendency to the formation of a vacuum in the pleura and pericardium, into which the lymph is drawn from the lymphatics, whilst blood is sucked in from the vena cavae. In *Fig.* 92 the chest is shown during

* Reproduced by kind permission of Sir Lauder Brunton, M.D., F.R.S., etc.

expiration and cardiac diastole when the walls of the pleura and pericardium are pressed together and lymph is ejected into the lymphatic vessels.

"Exercise within bounds thus tends to increase not only nutrition of the muscles, but of the lungs and heart."—"*The Physiological Basis of Education*," Sir Lauder Brunton, M.D., F.R.S., &c.

Other results of exercise are :—

(5) To develop the nervous system, (*a*) by the acquirement of new muscular co-ordinations under the control of the cerebro-spinal system, (*b*) by the exercise of such mental qualities as skill, courage, resourcefulness, etc., (*c*) by the development of a sense of power over conditions, including those connected with the voluntary activities of the body.

(6) To afford temporary relief to the tendency to congestion of the blood in the internal organs associated with long-maintained sedentary occupations, thus conducing to their more normal functioning and to general well-being.

(7) To develop and strengthen the muscles of the body, thus increasing its symmetry, utility and power of endurance, improving the digestion, increasing the vital capacity and preparing the heart for sudden calls.

(8) To induce, sooner or later, and to a greater or less degree, a feeling of fatigue, which is recognized as the result of the accumulation in the tissues of the chemical products of muscular activity.

Fatigue and the extent of the powers of endurance are chiefly subjective and individual, and no hard and fast standard can be adopted to which any number of people could be required to conform, even if condition of food, rest, sleep and work were identical. Both vary with age (power of endurance in the ordinary sense of the word is physiologically unattainable before 14 years of age), sex, temperament, season of the year, time of day, physique and general condition of mind and body, atmospheric pressure and degree of humidity. A high degree of humidity combined with a high temperature and a declining atmospheric pressure constitute a combination of conditions quite unsuited to muscular activity.

Refer to mental fatigue and its form of manifestation—loss of memory, confusion of mind, want of accuracy, fidgets, yawning—and to the influence of mental excitement on bodily fatigue; also to the economy of energy and diminution of fatigue which follow judicious and systematic exercise of

mind and body. Interest should be awakened in the methods of measuring fatigue by different forms of mental exercise, such as dictation or arithmetical problems, or by the use of instruments such as the Æsthiometer or the Ergograph.

The former records, by a delicate test, the degree of sensibility in some selected area of the skin, usually on the temple, before and after physical and mental exertion; such sensibility diminishes with fatigue, though to a very variable degree. The Ergograph consists practically of a weight suspended from a cord which runs over a pulley. The weight is drawn up by the rapid contraction of a finger and each contraction is recorded upon a revolving cylinder.

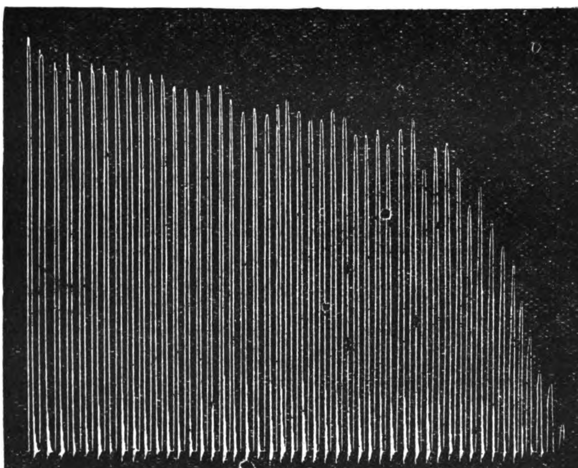


FIG. 93.* (After Mosso. Normal tracing from Dr. Maggiora.)

The amount of contraction is shown by the height of the curves traced, and it is found that after a while the contractions become less and less until they cease altogether. In some persons they stop suddenly while in others the failure is gradual.

The tracings in *Figs.* 93 and 94 were made by the same individual with the Ergograph; *Fig.* 93 shows a normal tracing. *Fig.* 94 illustrates the effect of mental work on muscular force. It was made after giving a lecture, and the tracings show that the contractions of the finger ceased much more quickly.

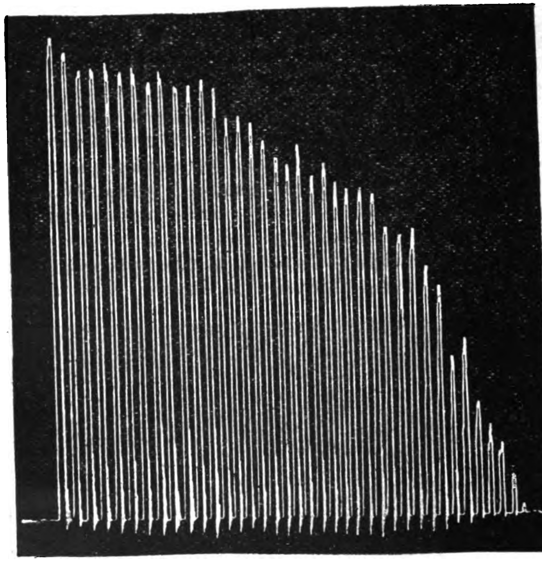
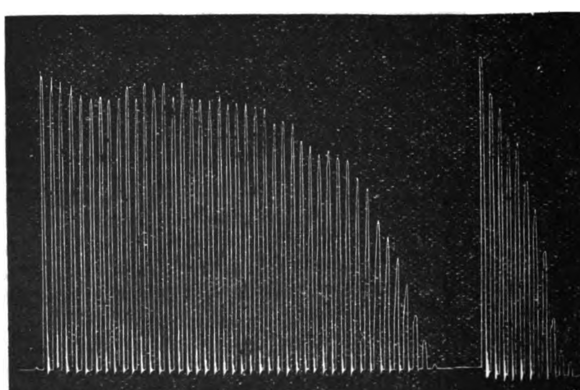


FIG. 94.* (After Mosso. Tracing from Dr. Maggiora, when fatigued by giving a lecture.)

Fig. 95 is another illustration of the same fact.



(*A*) FIG. 95.* (*B*)

After Mosso. Voluntary contraction. (*A*)—before conducting an examination. (*B*)—after examining nineteen candidates.

* Reproduced by kind permission of Sir Lauder Brunton, M.D., F.R.S., etc.

(*A*) shows a normal tracing taken before the subject conducted an examination. (*B*) demonstrates the exhaustion which followed the *viva voce* examination of nineteen candidates.

(9) Exercise also increases the demand for food and water to make good the losses sustained. The underfed or anaemic are unfit for much muscular exertion.

The results of physical exercise should be treated in detail with older pupils, who should be required to collect and present their own observations upon the subject, which should include the symptoms of fatigue and over exertion.

(An excellent summary of the conditions to be observed and the precautions to be exercised when taking physical exercise, will be found in Dr. F. J. Allan's "*Aids to Sanitary Science,*" Balliere, Tindall & Cox.)

(*B*) Classify under the following heads the different forms of exercise performed in the course of physical training:—

(1) Nutritive Exercises.
(2) Corrective Exercises.
(3) Control Exercises.
(4) Recreative Exercises.

NOTE.—These are very fully treated in the "*Report of the Inter-Departmental Committee on the Model Course of Physical Exercise,*" Eyre & Spottiswoode.

Under (1) would come running, walking, skipping, breathing and arm-extension exercises.

Under (2) come heel-raising, swinging from the horizontal bar or boom, and all movements designed to remedy some special defect.

Under (3) come balance movements, *e.g.*, walking on stilts, carrying books on the head, cycling, etc.

Under (4) come free play, and many games or movements which have become familiar from long habit.

(*C*) Mention and classify those games which develop the following qualities. At the same time state the age for which they are most suitable:—

(1) *Agility.*
(2) *Precision or Self Control.*
(3) *Strength.*
(4) *Grace.*

NOTE.—The following will serve as good examples under each head for children and young people, aged 6, 10 and 18:—

(1) Bean Bags or Spoon and Potatoe Races.
Rounders.
Tennis or Basket-ball.

(2) Ball Games and Hoop Bowling.
Loto or Stilts.
La Crosse, Croquet.

(3) Vaulting.
Tug of War.
Football (boys).

(4) Swaying and Clapping Movements.
Dancing.
Fencing and Dancing.

VII.—Influence of Habits and Environment on Health.

(*A*) Make a list of the daily habits which influence health, give reasons so far as you can. Classify them in 4 groups according as you consider they affect:—

(1) Health of Mind;
(2) Health of Body;
(3) Temperance; or
(4) Family well-being.

Do any of them appear in more than one group?

NOTE.—Advantage should be taken of this opening to train pupils to trace the law of cause and effect in human life as well as in the inorganic world. Teach them to exercise their observation upon the results of habits on daily well-being and efficiency.

With young children only the very simplest and most obvious examples could be taken, such as the weariness experienced in the morning when sleep has been curtailed owing to excitement and late hours the previous night, or the discomfort suffered when greediness has led to over-indulgence in unripe fruit or rich cake.

For older scholars more elaborate tabulation of habits and more detailed observations, deductions and explanations will be of great service, for they will serve to show the

intimate connection of mind and body, the wide scope of temperance and the effects on others of individual carelessness or ignorance.

Among the habits classified will be those of sleep (*see* Diagram for Number of Hours of Sleep required at different Age-periods, and refer to the conditions of quiet, fresh air, warmth and comfort necessary to secure the fullest degree of refreshment); exercise, mental and physical; personal and domestic cleanliness; regularity in food, in attention to the functions of the body, in work and in rest, in play and in other forms of recreation; the exercise of modesty, decency, and a respect for the feelings of others.

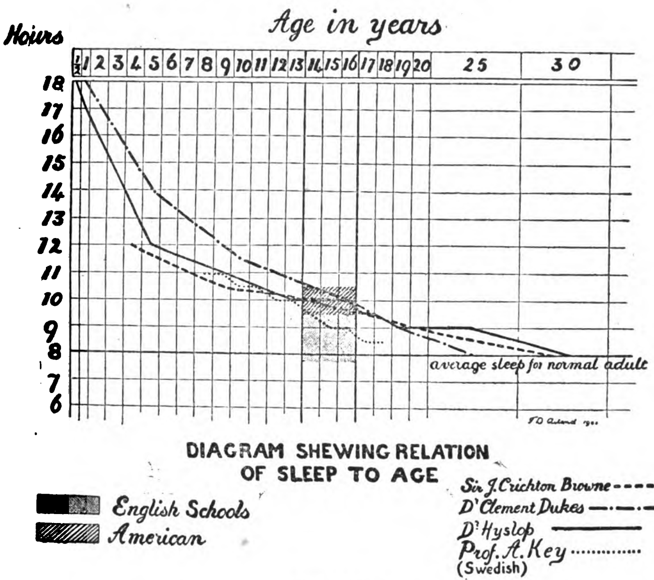


FIG. 96.*

Under (3) would be enumerated, for little children, restraint in expenditure of pocket money upon sweets and fruit, or of indulgence in certain kinds of food, or selfishness in play.

* The original of this reproduction was kindly lent by Dr. Dyke Acland.

For those rather older, Temperance would include (in addition to that exercised in food, drink and sleep), control over speech and actions, over the temptation to read unwholesome books and papers, or to look at improper sights; kindness to the weak and small, and willingness to devote part of their leisure to assist in family duties instead of spending all the time in amusing self.

For seniors, the scope of temperance should be shown to cover the exercise of moderation and self-respect in all the daily habits, in food as well as drink, in all forms of recreation as well as in the consumption of tobacco or in gambling, in the pursuit of business as well as of pleasure, in the maintenance of a true balance between duty to self and duty to others. It will be found that most of the common habits appear under each of the suggested groups.

Reference should be made to "*Characteristics of Life*," IX., Heredity, etc., *page* 34, to explain the origin of habits and to VIII. "*The Systems of the Body*," (*A*) III., *pp.* 97, 98, to explain their physiological basis and formation.

(*B*) (1) Give instances of the effects of environment (surroundings) upon health.

(2) Repeat the experiments performed in "PHENOMENA OF LIFE," II., *pp.* 18—20, (V.) *pp.* 27, 28, (VI.) *pp.* 29, 30, (IX.) *p.* 33, (X.) *p.* 35.

Do the lessons taught by these observations enable you to enlarge the number of instances given in (1)?

NOTE.—The opportunity is here afforded to link the subject of Hygiene very closely and attractively to the Conduct of Life in general and to other subjects in the school programme, such as history, geography or physiography. For instance, observation would be directed to the influence of urban, rural or marine surroundings upon the physique, and even to the different appearance of those who live under diverse conditions in close proximity to one another; to the effects of occupation, recreation, cleanliness, income or habits upon health; to the effects of climate, rainfall, soil, and altitude upon the wholesomeness of dwellings or of employment, and through them upon national prosperity (*cf.* the plagues and other illnesses fostered by ignorance of health laws). The need for such observations, supplemented by well-balanced deductions, was well summed up by Charlemagne, "Although right doing is preferable to right speaking yet must knowledge of what is right precede right action."

VIII.—First-Aid in Slight Accidents.

Materials: *Roll of clean boiled linen or absorbent gauze; handkerchief; cloth; thin jaconet mackintosh or oiled silk; unbleached cotton wadding; cotton wool; reel of Mead's adhesive plaster; 3 china dolls dressed as directed; soap; boracic acid powder; oxalic acid; nitric acid; carbolic acid; hydro-chloric acid; sodium carbonate; ammonia; vinegar; oil; litmus paper; red ink; cochineal; linseed meal; raw meat; taper.*

Apparatus: *Small bowls or basins; saucer; plates; pipette; c.c. measure; pair of forceps; knife or wooden spoon; bell-jar; metal tray; scissors.*

(*A*) *To wash and dress a cut or sore.*

(1) Prepare two small bowls or basins (*a*) and (*b*), a saucer or plate for soiled dressings, a roll of clean *boiled* linen, or some absorbent gauze, some cotton wool, adhesive plaster and a pair of forceps. Fill (*a*) with water which has been boiled and cooled to 40° C. (104° F.), support the injured part over (*b*). If the wound be covered, loosen the covering with forceps very gently, remove it and place it in the receptacle until it can be burnt.

If the covering adhere to the surface, or if there be no dressing on the wound, the procedure will be invariably as follows:—Dip a tuft of cotton wool in (*a*). If the fingers be used they must be previously washed in hot water with soap, if the forceps be used they must first be boiled. Allow a streamlet of water from the wool to pour over the covering if adherent to the cut or sore into (*b*). Do not touch the dressings or wounds with the wool, if this occur throw the tuft away and take a fresh piece.

Continue the bathing process after the dressing has dropped off into (*b*) in order to cleanse the part, then mop it gently dry with fresh tufts of wool.

(2) If it is a clean cut, bring the edges together by gentle pressure, cover it with several thicknesses of boiled

linen or with several layers of absorbent gauze, cut somewhat larger than the injured part. Hold the dressing in position with a bandage or a strip of plaster (*see page* 519) according to the size, severity and position of the injury.

(3) To illustrate the necessity for two basins, allow a few drops of coloured paste or gum to fall on the upper part of one finger. Support the finger over a basin of water, bathe off the paste or gum with a mop of wool.

The discolouration of the water will show that pus or other unhealthy matter, such as dirt, being transferred to the water would subsequently re-infect the wound if the water into which it is received were employed for bathing purposes.

(4) If there is any throbbing in the wound, or if there be broken skin or any drops of pus, prepare a hot boracic compress as follows:—

Make some boracic acid lotion by pouring 500 c.c. (about 1 pint) of boiling water upon 14 grams (1 tablespoonful) boracic acid powder previously placed in a clean jug.

Spread a warm handkerchief or cloth over a basin, place a pad of boiled linen or clean gauze upon the handkerchief or cloth, fold this over the pad, pour the boiling boracic lotion over the cloth, wring out the moisture until, when the cloth is unfolded, the pad feels dry to the touch; transfer this quickly to the sore place, wrap it well round the part and cover immediately with a piece of thin jaconet mackintosh or oiled silk, cut to completely envelop the dressing. Hold it all firmly in position with a bandage (*page* 520). Repeat every four hours until the throbbing is relieved or the sore is healed.

The lotion can be boiled and used on several consecutive occasions, if no soiled dressings come in contact with it. The pad must be renewed as each fomentation is applied *if* the surface of the skin is broken.

This treatment may be used in the case of wasp or gnat stings where there is pain and swelling.

(*B*) *To Dress a Bruise.*

(1) Hot boracic fomentations as in (*A*) afford much relief to large bruised surfaces.

(2) Strips of gauze, lint or linen steeped in spirit lotion (1 part spirits of wine or eau-de-cologne to 2 parts of cold water), laid over or wrapped round a pinched finger relieve pain if frequently renewed, but can only be used if the skin be unbroken.

(3) Hazeline Snow or Cream spread over the injured surface is a useful remedy in many cases of "black eyes," bruised knees, etc.

(4) A very severe bruise, caused by the fall of a heavy weight on any part of the trunk, hands or feet, may be temporarily relieved until the doctor's arrival, so long as the skin is unbroken, by the application of a large linseed poultice, which should completely envelop the part and be covered by mackintosh, brown paper or cotton wadding to retain the heat.

Make the poultice as follows:—

Heat a basin of convenient size in an oven or by filling it with boiling water; heat the knife for mixing the meal and the linen upon which the poultice is to be spread by the same means.

Take the heated basin, hold a kettle of boiling water in the right hand and pour a small, steady stream of water into the basin. Meanwhile, sprinkle the linseed meal into the basin with the left hand until the mixture resembles thin batter. Put down the kettle and beat the poultice quickly with a large flexible knife or wooden spoon, adding more linseed meal with the left hand until the desired consistency is obtained.

Turn out the poultice on to the linen, spread it out evenly to the square, oblong, triangular or other shape most suitable for the part to which it is to be applied, turn over the edges of the linen, carry it between two hot plates to the patient's side, but do not put it on hurriedly lest the skin should be scalded by the damp heat.

If a child, paint over the surface to be poulticed with a little warm oil or vaseline before putting on the poultice.

NOTE.—Cuts, wounds and bruises may be *incised* with sharp instruments, *punctured* with splinters, needles or tools, *contused* with stones, hammers, or by falls, *lacerated* by pins, nails, etc., *poisoned* by dirt or by the bites of insects or animals.

Impress the great importance of controlling hæmorrhage, removing dirt, and employing only scrupulously clean hands, dressing, or bandages, when attending to any kind of injury. Caution against hasty measures when a needle or fish-hook is broken into any part of the body.

It is wiser and better economy to secure skilled assistance and advice where wounds are badly lacerated or contused, when they are suspected of being poisoned, or when there is throbbing or discharge. A boracic fomentation is, however, a safe application until a doctor arrives, unless there be severe bleeding.

(*C*) *To Control Bleeding.*

(1) Prepare several pads made of 4 layers of unbleached cotton wadding lightly covered with butter muslin. Draw up varying quantities of red ink or of water coloured with cochineal into a pipette, in accordance with the directions given below. Expel these upon the pads and train the eye to associate the amount of the liquid spilt with the size and appearance of the stain upon the pads.

Employ the coloured solution as follows :—

Draw up and expel consecutively—

(*a*) 1 drop, 2 drops, 4 drops, 8 drops, 16 drops, 32 drops, 64 drops (about 2 c.c. or 1 teaspoonful).

(*b*) 1 c.c., 2 c.c., 4 c.c., 8 c.c., 16 c.c., 32 c.c., 64 c.c., 100 c.c.

(*c*) 25 c.c., 50 c.c., 75 c.c., 100 c.c., 150 c.c., 200 c.c., 300 c.c.

Repeat and vary the order of the above quantities until able to estimate with fair accuracy the amount of liquid used in samples of stains made by a companion, while carrying out a similar demonstration.

(2) Prepare some coloured solution in a basin. Fill a rubber tube (60 cm. × 1 cm., 25 ins. × $\frac{3}{8}$in.) with the solution and support it horizontally so that each end is immersed in the liquid while the tube remains full.

Make a small hole in the upper surface of the tube towards one end. Notice that the contents flow out slowly and steadily. Compress the tube repeatedly and forcibly at the end nearest the pricked hole. Observe how the liquid is squirted out with each compression.

This experiment gives a general idea of the great difference between the way in which the blood returns through the veins to the heart against gravity and from parts remote from the propelling force, and that in which it spurts from the heart through the arteries under the influence of the heart's beats. (VIII.—"The Circulatory System," (III.) (*B*), *pp*. 116—118).

Note.—All *continued* or profuse bleeding must be referred to a surgeon with the least possible delay, but young people should be prepared to keep calm and to act promptly when confronted with accidents accompanied by loss of blood, the first sight of which is very alarming. Immediate and appropriate pressure upon the bleeding spot is the first and most important aid to render in all cases of hæmorrhage, as by this means it can be generally controlled.

If the blood spurts in bright red threads or streams instant pressure on the bleeding spot is of major importance, it must be exerted against a bone (in order to compress the artery which has been severed), on that side of the cut nearest the heart. Meanwhile, knot a handkerchief or tie a stone or coin in a handkerchief with the disengaged hand and substitute this for the thumb or finger as quickly as possible, pressure will then be more easy to maintain.

If trained in First-aid, direct a bystander, if present, to exert pressure upon the main artery which connects the cut artery with the heart; it may be necessary to remove clothing for the purpose, if the femoral artery for instance has to be controlled. Disturb the injured person as little as possible, keep him recumbent and cool, and permit no stimulants, which only quicken the heart's action and add to the difficulties. If single-handed, do not risk increasing the hæmorrhage by

attempting more than pressure on the bleeding spot. If the blood be dark red and trickle in a steady stream it proceeds from a vein, the treatment is identical except that the main vessel must be controlled on the side of the wound furthest from the heart.

Severe bleeding from more or less superficial cuts is usually checked when the edges of the wound are kept in close contact; if this fails, the application of either very hot water, ice cold bandages, or alum and water will usually suffice to do so, at least until a doctor can be fetched. The application of tourniquets should be explained, but unless the hæmorrhage prove otherwise uncontrollable their use should not be advocated as they cause great pain.

In bleeding from the nose, compress the nostrils, apply cold to the forehead and back of the neck and sit quiet. If persistent and severe, plug the nostrils with wool dipped in a solution of salt and water, weak alum and water, or tannin.

If bleeding prove troublesome from the socket of an extracted tooth, wash the hands well and exert pressure on the bleeding spot with a finger, if this fail, try ice or a plug of wool as directed for the nostrils, until skilled assistance can be secured.

(*D*) *Accidents from Heat.*

(1) *Fire or Water.* Burns are caused by "dry" heat, *i.e.*, by heat alone, scalds by "moist" heat, *i.e.*, by heat plus vapour or liquid.

In each case the air must be excluded from the wound as soon as possible.

Mention substances to be found in every house suitable for application until a doctor comes to dress the injury.

NOTE.—Clean rags soaked in glycerine, vaseline or oils (salad, castor, etc.), lard or butter, and covered with cotton wool are to be preferred for burns. Flour, chalk, magnesia, baked or boiled potatoes and carbonate of soda are admissible in the absence of suitable oils, but it is difficult subsequently to cleanse the surface of the wound, they can, however, be dusted or sprinkled thickly over scalds where the skin is unbroken, and the injured part must then be covered with cotton wool.

In the case of a badly burnt child, immersion, clothes and all, in a warm bath (40° C. 104° F.), excludes the air and is valuable in case of shock to the system, which is usually very severe.

Emphasize the fact that clothes may only be *cut* off (not removed in the ordinary way) in the neighbourhood of burns or scalds; that the sufferers must be kept warm by hot-water bottles, and that no blisters may be pricked except under the doctor's orders.

(2) Dress as follows, 8 small china dolls, (*a*), (*b*) and (*c*).

(*a*) In cotton garments;
(*b*) In some form of wool;
(*c*) In flannelette.

Take a metal tray, support (*a*) about the middle of its surface and set light to some portion of its clothing with a taper.

Watch the course of the flames for a few seconds, then tip the doll over with a glass rod upon the burning clothing. How does this affect the flames? If they continue, cover the doll with a bell-jar. Are they quickly extinguished?

Repeat this procedure with (*b*) and (*c*).

In which instance is combustion most easily controlled?

NOTE.—Children must be taught, in the emergency of their clothes catching fire, to throw themselves instantly on the ground and to roll over on to the burning part, or to throw another person on the ground at once if such an accident occur. If in either case there is time to seize a thick rug, curtain or table cloth to envelop the burning clothing, the flames will be even more rapidly extinguished.

(*E*) *Accidents from strong Chemicals.*

(1) Observe the effect of strong acids or alkalies upon flesh.

Place 4 small pieces of raw meat on a plate and mark them, (*a*), (*b*), (*c*), (*d*). Add to:—

(*a*) A few drops of oxalic acid.

(*b*) A few drops of nitric acid.

(*c*) The same amount of a saturated solution of caustic soda.

(*d*) A similar quantity of carbolic acid.

Observe the results in each case, which more or less reproduce the corrosive effects of these chemicals upon the tissues of the human body.

NOTE.—Whether the injury be external or internal the broad lines of prompt treatment are the same; drench the part with water to remove the chemical (by drinking or bathing), neutralize an acid with an alkali or *vice versa* by the use of the appropriate antidote, follow this with an oil dressing if external, or by swallowing oil or white of egg if the chemical has been drunk; meanwhile send for the doctor, the messenger telling him for what reason his services are wanted.

(2) Perform the following experiments :—

(*a*) Neutralize an acid by an alkali.

Add 40 drops of hydrochloric acid to 100 c.c. of water in a tumbler.

Make a saturated solution of sodium carbonate in a c.c. measure and add cautiously to the acid. Note the amount required to neutralize the acid as tested by litmus paper.

(*b*) Neutralize an alkali by an acid, or saponify with oil.

Take (i.), 100 c.c. of a strong solution of caustic soda and (ii.), a similar quantity of ammonia. Add sufficient quantities of vinegar to neutralize the alkali and of oil to form soap, to the respective solution. Observe the quantities required to effect your purpose.

NOTE.—Dilute solutions of soda or potash, lime-water and a mixture of magnesia and water are good antidotes for an acid; lemon or orange juice may replace vinegar in the case of an alkali.

It is well to repeat these observations with junior students until the large quantity of antidote required to neutralize such strong corrosives is thoroughly realized. Impress the fact that no emetics must be given where these potent acids and alkalies have been swallowed, as further damage would result to the already injured stomach.

Probably there will be no stain or corrosion of the lips, the smell and distressing sensations will guide to the cause of the accident. Emetics are, however, the best "first-aid"

remedies where arsenic, mercury (corrosive or sublimate), antimony (tartar emetic), lead or phosphorous have been swallowed.

After vomiting has resulted from a draught of salt and water or weak mustard and water, raw eggs or milk should be administered, or oil (which is always safe except when *phosphorous* is the cause of the accident), especially if there be delay in the arrival of skilled assistance. In the case of poisoning with iodine, use any form of starch or chalk as an antidote, with large quantities of water to dilute the irritant.

(*F*) *To apply Plaster.*

(1) *To a cut Finger.*—Cut a piece of plaster from a reel of Mead's adhesive plaster 5 cms. (2 inches) long × 3 cms. (1⅛ inch). Reduce the width for a distance of 1 cm. from each end by paring off 1 cm. on each side, and split up each end for a short distance.

Fig. 97.

Fold the plaster in half, and gridiron a space of 2 cms. (⅘ in.) in the middle (*see Fig.* 97). This will allow any secretion to escape through the dressing. Apply a piece of absorbent gauze or boiled linen over the cut, place the broad gridiron of plaster over the dressing and draw the split ends round the finger, fixing them firmly to the finger.

(2) *To the Tip of a Finger or Toe.*—Cut a piece of plaster 8 cms. (3⅛ ins.) long × 2 cms. (⅘ in.) broad, and shape it into a capital T (*Fig.* 98). Place the T upside down, lay the top joint of the finger, nail downwards, on the cross piece, fold the tail over the tip so that it covers the under surface of the finger as it lies uppermost on the supporting surface; wrap first one end of the cross piece round the finger and fix it firmly and then the other; a neat and firm support will thus be formed.

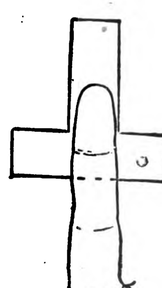


Fig. 98.

(8) *To the Heel.*—Cut a strip of plaster twice the length of the foot and 4 cms. ($1\frac{1}{2}$ inches) wide. Place the middle of the plaster over the dressing at the back of the heel, bring the ends round the foot on each side, below the ankles, and cross them at the base of the toes, splitting the ends to increase their adhesive action. Gridiron that portion of the plaster immediately over the dressing (*see Fig.* 97).

NOTE.—Plaster can be applied in similar fashion to the knee or elbow. Strapping should be gently removed by unfixing the two ends and supporting the cut or sore place with the finger and thumb of one hand, while with the other the plaster is loosened, working *towards* the wound. Tiny hairs adhere tightly to the plaster and cause great pain if it be hastily removed, in addition there is the added risk of re-opening a cut or nearly healed wound.

(*G*) *To apply a Handkerchief Bandage.*

NOTE.—Children from 10 years of age should be made practically familiar with the use of the handkerchief bandage which suffices for the little needs of daily life, such as cuts, grazed knees, the keeping in place of dressings or fomentations, the support of sprains, etc. Excellent directions are given by Mrs. Alfred Paine in her little penny book on the "Home Use of the Triangular Bandage," published by Allman and Son.

These experiments and observations are merely designed to give practical experience on some useful points which permit of experimental treatment; they cannot in any way replace the more comprehensive and detailed acquaintance with First-aid which it is the duty of all to acquire.

The knowledge which it is supposed that children or young people have gained should be tested at intervals by demanding of them a practical demonstration of what they would do *on the spur of the moment* under emergencies. For instance, one or other of the following examples might be selected and five minutes reflection allowed before the demonstration is given:—

(1) A boy has cut his thumb severely with a Sloyd tool. How will you check the bleeding and dress the wound ?

(2) A child falls in the playground, lacerates its knee and gets dirt into it. Show how you would cleanse and dress the injury.

(3) A child attends school with a festered finger wrapped in dirty rag. Show how you would proceed to dress the sore.

(4) A case of violent nose-bleeding occurs at home. What will you do ?

(5) A child is seized with sudden vomiting and brings up much dark-coloured blood. What will you do till the doctor comes ?

(6) A heavy blackboard is upset; in its fall it pinches the thumb of one child and severely bruises the foot of another. How will you attend to both injuries ?

(7) Two children playing with matches set light to their clothes. They run wildly from one room to another. One receives deep burns on hand and arm, the other has a large superficial burn covering chest and back. How would you act ? Show your first-aid treatment of each case.

(8) A disturbance arises amongst the children during the lunch hour. Approaching the group you find:—one has something in his eye, another has pushed a pea into his ear, a third has swallowed a needle, a fourth is choking from a fragment of food wedged in the throat. How would you attend to each mishap, and in what order ?

(9) A child falls down insensible. How would you judge whether the cause be (*a*) Faintness; (*b*) Sunstroke; (*c*) Brain injury ? What symptoms would probably be present if it were a case of epilepsy or hysteria ?

XXII.—CLOTHING.

Loss of heat by the skin. Object of clothing. Relation of surface to mass. Relation of weight to warmth. Influence of colour on the absorption of heat rays. Materials used for clothing; their relative conductivity; hygroscopic properties; inflammability. Test for quality. Methods of washing clothing.

I.—Loss of Heat by the Skin.

MATERIALS: *Water.*

APPARATUS: *Bath thermometer; beaker.*

Demonstrate as follows the loss of heat from the skin:—

(*A*) *By Evaporation.*

Repeat "THE HUMAN BODY," II. (*D*) (*page* 78) and "ELEMENTARY STUDY OF THE PROCESS OF METABOLISM," (*B*) (2) (*page* 198).

The cooling effect of this constant evaporation will be confirmed by the following experiments (after Professor Murbach):—

Note the temperature of the room as recorded by an ordinary thermometer (a bath thermometer is most convenient for the purpose). Prepare a vessel and fill it with water at a temperature of 2° C. (5° F.) below that of the room.

Immerse the bulb of the thermometer in the water until the mercury becomes stationary. Note the degree it registers.

Withdraw the thermometer from the water and hold it in the air, watching with great attention for any variation in the temperature it records.

The result indicates the fact that the evaporation of water from a surface lowers its temperature (*cf.* "SOME CHARACTERISTICS OF WATER," III. (*C*) (3), *page* 64).

(*B*) *By Conduction.*

Note the temperature of the room as in (*A*). Then hold the bulb of the thermometer in the palm of the hand, meanwhile count 100 slowly.

To what level has the mercury risen in the thermometer? In this case the heat of the body has been conducted to the thermometer through the skin.

(*C*) *By Radiation.*

Make a little cup with the left hand, of which the forefinger and thumb will form the brim.

After noting the temperature of the thermometer as in (*A*), hold the bulb of the thermometer inside the hollow formed by the left hand in such a way that it does not come in contact at any point with the skin (a distance of ·5 cm. ($\frac{1}{5}$ in.) should, if possible, be secured). Watch for any change of temperature recorded by the thermometer. The result illustrates the fact that heat radiates through air. (*cf.* "AIR," II. (*D*), *page* 47).

NOTE.—Heat may be transmitted from one body to another by *radiation*, *conduction* or *convection*. For instance, the heat of the sun reaches us by "radiation," that is, it is transmitted across space in rays or straight lines from its source to our bodies, without appreciably affecting the temperature of the intervening medium (the air) through which it passes.

Heat is said to be "conducted" when it passes from the hotter to the colder parts of a body by way of the intervening material. The sensation of cold experienced when a metal instrument is grasped, results from the rapid conduction of heat from the skin to the more remote parts of the object.

Again, when a vessel of water is heated at the bottom ascending and descending currents are produced in the water, these are the main sources by which heat is distributed throughout the liquid. This mode of heat transmission is called "convection."

Bodies conduct heat with different degrees of facility; if the power of conduction in silver be represented at 100 it is reduced in copper to 96, in iron to 20, in water to ·20, in wood to ·03, in wool and in paper to ·01, while air is the worst of all conductors, its power amounting only to ·0005.

II.—The Object of Clothing.

MATERIALS: *Flannel or baize; water.*

APPARATUS: *Flasks; thermometer; retort stand; Bunsen burner.*

(*A*) Take two flasks (*a*) and (*b*). Fill (*a*) with cold and (*b*) with hot water. Note and record the temperature in each case.

Immediately envelope each flask completely in a bag made of three thicknesses of flannel or baize and set them aside for half an hour under exactly similar conditions.

Unfasten the bag and take the temperature of (*b*), then uncover and test the temperature of (*a*). To what extent do the temperatures differ from those first recorded.

(*B*) Return the bottles to their bags, and take the temperatures of the water again before closing the bags completely.

Place them at a distance of 60 cms. (about 2 ft.) from a coal fire for 15 minutes, or at a distance of 30 cms. (1 ft.) from a Bunsen burner for the same length of time; again take and record their temperatures.

Do your temperature records support or negative the following statements?—

(1) That clothing maintains but does not generate heat.

(2) That the layers of air imprisoned between layers of clothing serve to maintain the normal temperature of the body alike under conditions of moderate heat or cold.

The heat was conserved in (*A*) (*b*) by the non-conducting properties of the air entangled in the meshes of the woollen cloth. For the same reason external heat from the fire or gas passed slowly and to a very limited degree to (*a*) in (*B*).

Does this throw light upon the fact that cold feet remain cold even after being cased in woollen socks and warm boots? When, however, they are first warmed by active exercise, or by the proximity of a bottle of hot water in bed or on the floor of a railway carriage, suitable clothing then preserves the warmth generated.

(*C*) Consider for what reason sufferers from cold hands and feet are directed to take active exercise. Why does the sensation of warmth which succeeds exercise last for a longer

period than when the hands or feet are warmed by exposure to a fire or other source of artificial or external heat?

NOTE.—Emphasis will, of course, be laid upon the use of clothing for purposes of propriety and personal adornment, but the attention of pupils will be directed chiefly at this point to the function of clothing in the regulation of the body temperature and in the maintenance, by its means, of an artificial climate round the body. The normal temperature of the body is, in winter, for instance, often 30° C. (54° F.) above that of the external atmosphere, yet it remains constant.

Air is the best known non-conductor of heat, and clothing has been aptly described as "a net to catch air." The air space, formed by the clothes round the body, prevents the penetration of excessive heat to the body when the external temperature is higher than that of the body or its undue loss in cold weather, when the temperature is much lower.

Clothing should be loose in summer and close-fitting in winter; it should provide for the free passage of air and moisture and on no account should it consist of materials, such as leather, for instance, likely to retain the products of excretion.

The maintenance of an equable bodily temperature by clothing is an economic, hygienic and dietetic measure, it promotes growth and bodily activity and maintains the normal output of energy, thereby securing efficiency in work; it lessens the quantity of food otherwise required for these purposes, and it directly conduces to health by promoting evaporation from the skin.

III.—Relation between Mass and Surface Area in Loss of Heat.

MATERIALS: *Water.*

APPARATUS: *Wide tumbler; narrow jar; 2 thermometers; retort stand; Bunsen burner.*

Prepare two glass vessels; (*a*) a wide tumbler and (*b*) a tall, narrow jar; they should be of the same capacity but of different shapes.

Heat to a temperature of 70° C. (158° F.), the quantity of water necessary to fill (*a*) and (*b*) when divided into two equal portions.

Fill the vessels with the hot water and test the temperature at intervals during half-an-hour, noting the relative rapidity of loss of heat in each case.

The observations will be more interesting and accurate if two thermometers be used, and one be suspended in each vessel from the ring of a retort stand.

NOTE.—The area of a body varies as the square of its dimensions, while its volume varies as their cube. The results of this experiment will show how much more rapid is the loss of heat from (*b*) than from (*a*).

This point is of great importance in the care and clothing of young children; the smaller the infant the larger is its surface relatively to its mass, consequently the greater its loss of heat by evaporation, because the surface of a human body is an evaporating one.

To further illustrate this fact prepare two cubes (*a*) of 2·5 cms. (1 inch), and (*b*) of 25 cms. (10 inches) edge, and measure their superficial area.

In (*a*) there are 37·5 sq. cms. (6 sq. ins.) of surface to 15·6 cubic cms. (1 cub. in.) of bulk. In (*b*) there are 3,750 sq. cms. (600 sq. ins.) of surface but 15,625 cubic cms. (1,000 cub. ins.) of bulk. Therefore if an infant was $\frac{1}{10}$ the size of an adult, in addition to its feeble powers of heat generation, it would have ten times as much surface in proportion to its size from which to lose body heat. As a matter of fact the difference, which is a progressively diminishing quantity, varies from $\frac{1}{4}$ to $\frac{1}{3}$ in infancy and early childhood according to age.

It is true that owing to the vaso-motor mechanism (*pp*. 200, 201), blood is withdrawn from the exposed surfaces, nevertheless growth and development are more or less injured by constant chilling of the surface, for both are inextricably interwoven with the due provision and proportions of vital heat and nutrition. The more heat there is lost from the body, the more nutriment must be diverted from the maintenance of the heat necessary for other manifestations of energy, and consequently the less there is available for the building-up of the body.

A recent writer on Physical Efficiency attributes the often stunted, delicate appearance of small boys to insufficient clothing, and strongly advocates the Scotch kilt for the years immediately succeeding infancy; he contrasts with these

pinched looking boys the taller, better nourished girls who are more suitably clad, especially round the digestive organs. ("*Physical Efficiency*" (*Chapter V.*), *J. Cantlie, M.A., M.B., D.P.H.—Putman*).

Call attention to the following points :—

(1) That the neck does not need wrapping up—boas and high collars are a fruitful source of sore throats and colds; suggest the great advantage of knitting wool into undervests, stockings, or wristlets rather than into "comforters."

(2) That tight garments are neither graceful, warmth-producing, nor healthful.

(3) That weight and warmth are not synonymous in the case of garments.

(4) That cheap, stiff corsets for girls or joined braces for boys are not necessary, economical, or healthful. (The advantages of knitted corsets without any steels, but just kept in place by a pair of pliable whale bones in front and laced with elastic, for girls, and of the separate brace for boys should be demonstrated; advice alone is generally disregarded).

(5) That no beauty exists in pointed toes to the boots or shoes—these cause deformity and suffering, and interfere with useful activity or wholesome enjoyment. (Refer to VII. "*The Human Body*," I. (*C*) (7) *page* 74.)

(6) That neglect of ordinary common-sense care in the matter of suitable clothing is injurious to the individual, brings expense and anxiety to his family, and may involve an economic loss to the nation through his premature death or prolonged illness.

The general custom of wearing ready-made clothing leads to frequent constriction of chests, arms and waists, and to the sacrifice of health to a mistaken idea of what is smart (*e.g.*, open-work or pneumonia blouses).

The results, especially of wearing undergarments got-up for their attractive appearance rather than for the careful choice of what is healthful, suitable and durable, should be put very plainly before elder girls.

IV.—Comparative Value of Weight or of Layers in the Warmth of Clothing.

MATERIALS: *Cloth; flannel; flannelette; silk; calico.*

APPARATUS: *Flasks; rubber corks with one hole; thermometers; retort stand; Bunsen burner.*

Take two flasks of similar shape and capacity (*a*) and (*b*). Fill both with water and raise to boiling point over a Bunsen burner. Remove the flasks from the source of heat and *quickly* fit in each a rubber cork through which a thermometer has been passed.

Place (*a*) in a bag made of a single layer of material of given weight. Place (*b*) in a bag made of two or more layers of material, of which the combined weights equal that used for (*a*). Record the readings of the two thermometers at intervals of 5 minutes during one hour.

NOTE.—This experiment is designed to illustrate the fact that thin clothing worn in successive layers is warmer than the same amount of material closely woven into a thick cloth, on account of the air imprisoned between the layers being so bad a conductor of heat; hence the comfort experienced in cold weather from wearing mittens over gloves, or gaiters over stockings. For the same reason winter cloaks are wadded with cotton wool. A *very* densely woven material is however warm because it interferes with free evaporation from the skin, a characteristic shared with fur, leather and mackintosh. It has been estimated that, for efficient protection of the body in different temperatures, a thickness of 1·7 mm. suffices in extreme heat if the material worn be wool and loosely woven; 3·3 mm. is sufficient for ordinary Summer wear; 5·9 mm. is necessary in Spring and Autumn; and 12·6 is required in Winter. For extreme cold an impervious material such as fur becomes necessary.

V.—The Influence of Colour on the Absorption of Heat Rays.

MATERIALS: *Paint or enamel (black, white, blue, red, green, yellow, and grey); chalk; litmus solution.*

APPARATUS: 7 *small tin flasks; rubber cork with one hole; very fine glass tubing; Argand gas burner.*

Procure seven small tin flasks, such as have contained oil for bicycle lamps.

Coat each tin with a *thin* layer of paint or enamel as follows:—(1) Black; (2) White; (3) Blue; (4) Red; (5) Green; (6) Yellow; (7) Grey.

When quite dry, fill each tin with coloured fluid (as water coloured with cochineal or litmus), then insert a rubber cork through which passes a length of *very fine* glass tubing which should extend 16 cms. (6¼ ins.) above the corks. Attach a thin paper scale to each tube, ruled in millimetres, as in "SOME PROPERTIES OF WATER," III. (*A*), *p.* 63. Draw a circle in chalk on the table, 30 cms. (12 ins.) in diameter. Place an Argand gas burner in the centre of the circle, light it and arrange the flasks at equal distances around the lighted burner. Gradually the fluid in the flasks will expand with the heat radiated from the burner and will rise in the tubes.

Record the readings from the scale in each flask at short intervals during half-an-hour.

NOTE.—The results of the various readings will appear approximately in the following order, from lowest to highest:—white, grey, yellow, green, red, blue, black, though a *dark* green will absorb more heat than a bright red. This experiment therefore confirms the well-known fact that white is the best protector against heat; then light grey or pale yellow. Elaborate investigations have shown that where white registered 37·8 C. (100° F.), pale straw registered 39° C. (102° F.), dark yellow 60° C. (140° F.), light green 68·5° C. (155° F.), turkey red 74·5° C. (166° F.), dark green 76° C. (168° F.), light blue 92° C. (198° F.), dark blue 95·5° C. (204° F.), and black 97·5 C. (208° F.)

The influence of colour is of course exercised only when worn as the outside garment. The fallacy of scarlet flannel being "anti-rheumatic" should be exposed.

VI.—Tests for Freedom of Movements in Clothing.

MATERIALS: *Blackboard; chalk; tape measure.*

(*A*) *The Respiratory and Digestive Functions.*

Stand upright with the back to a wall. Touch its surface with the back of the head, the elbows and the heels. Draw a prolonged, very deep breath, expire very slowly.

Can this action be performed without any sensation of restriction or the bursting from their fastenings of buttons or hooks.

If any difficulty be experienced, unbutton coat, waistcoat or dress bodice, and repeat the effort.

Remember that the power of deep breathing and of free expansion of the lungs is closely connected with the vital capacity, the powers of endurance and resistance to disease. Refer to "THE RESPIRATORY SYSTEM," I., II., III., IV., V., VI., *pp.* 133—143, also to "PERSONAL HYGIENE," *pp.* 491-2.

It is well to remember that wherever there are ribs there are lungs behind them; any constriction of the ribs will consequently interfere with free respiration.

The clothing should permit of the periodical variation in size natural to the stomach and intestines, also it should allow of the "churning movements" of these organs connected with the digestive process, which are of course hampered by tight garments round the trunk.

(*B*) *The Muscular Functions.* (Posture, exercise, etc.)

(1) Stand up in the position advocated in "PHYSICAL EXERCISE," *pp.* 493-4 (*Fig.* 81).

Can the head be held erect and the chest thrown forward without any difficulty or constraint being caused by the dress (in girls), or by the braces or waistcoat (in boys).

Loosen or remove the articles which interfere with a good position, and notice the increased ease with which it can be assumed and retained.

(2) Arrange the dress as usually worn. Raise both arms above the head so that they are parallel with the ears when the head is held erect, then swing them round four times, retaining the same position of the head.

Does the clothing permit these exercises to be performed while maintaining the right position of the body, head erect, chin back, chest forward, weight on fore part of the feet.

If the head poke forward and the weight of the body fall on the heels loosen the garments as in (1), and then repeat the movements. Does this contribute to greater facility of execution.

NOTE.—These tests could be carried out advantageously in the gymnasium before any change of dress is made, and repeated when suitably clothed in a woollen jersey or loose serge costume.

It is wise to caution boys against the habit of wearing a belt round the waist as a substitute for braces. Braces if "separate," instead of "joined," can be quite hygienic, whereas a belt exercises injurious pressure upon the abdominal organs and may cause serious and painful illness. A belt if worn to support trousers must be placed *below* the level of the top of the hip bones, not between them and the ribs.

(3) (*a*) Cover the surface of a blackboard with chalk, place it upon the floor, remove one boot or shoe and stand firmly upon the board with only the stocking as a foot-covering on the one foot, but with the boot or shoe on the other. Compare the prints of the two feet which will remain when they are removed from the board. Do they correspond in shape, especially in the width and form of the forepart of the feet?

(*b*) With a tape measure compare the dimensions of the circumference of the foot taken round the joint of the big toe and the base of the little toe with the circumference of the boot taken at the same point. Which of the two is the larger?

(*c*) Compare the shape of the foot, especially the development of the toes, with *Fig.* 35 (*page* 146), *Fig.* 36 (*page* 147), and *Fig.* 39 (*page* 157).

NOTE.—Remind the pupils that no posture can be long maintained and no active exercise can be enjoyed if the feet be pinched and cramped into footgear too small or misshapen. The feet form a firm base for the human body (their size being a direct result of the erect position which distinguishes man from other animals), and they permit of equilibrium being maintained during the almost infinite series of movements he performs with trunk and arms. Corns, deformed or cramped

toes, chilblains, and cold feet all suggest ill-fitting and tight boots, but it is not necessary to go to the other extreme and go bare-foot or wear sandals. The trade will supply boots to fit the natural form of the foot when the public demand is sufficiently emphatic.

VII.—Observations on Relative Conductivity of Heat in Materials used for Clothing.

MATERIALS: *Calico; flannel; flannelette; silk (these samples should, as far as possible, be woven of the same texture); litmus solution; water.*

APPARATUS: *Flat-bottomed flasks; glass tube; beaker; c.c. measure; rubber corks with holes; measured ruler; forceps; retort stand; copper cylinder; Bunsen burner.*

(*A*) Make an air thermometer as follows:—Take a small flat-bottomed flask (*a*) and fit it with a rubber cork through which just passes one end of a long, narrow, straight, glass tube (40 to 45 cms., 16 to 18 inches). Pass the other end of the tube through another rubber cork which has been previously fitted to a large flat-bottomed flask (*b*). This cork must have a second hole in it by which air can escape.

Three-parts fill (*b*) with litmus or other coloured solution and connect (*a*) with (*b*); invert (*a*) by inserting the second cork in (*b*); the tube should extend well below the surface of the liquid.

Thoroughly warm the hand and place it on (*a*). Note how the warmth of the hand causes the air contained in (*a*) to expand, in evidence of which bubbles will be seen passing into the liquid from the bottom of the tube in (*b*). Remove the hand, watch the results as the air contracts in (*a*) (*cf.* "*Air*," II. (*B*), (*C*), *pp.* 46, 47).

When the liquid is stationary in the tube prepare a paper scale (20 cms. × 3 cms. = 8 ins. × $1\frac{1}{4}$ ins.) divided into millimetres, and fix one edge with gum to the glass tube where it emerges from the cork of (*b*). Note the level on the scale. The thermometer is now ready for use.

(*B*) Take similar sized pieces of the following materials (10 cms. or 4 inches square is a convenient size):—(1) Calico; (2) Flannel; (3) Silk; (4) Flannelette.

Prepare a vessel in which the water is kept as near boiling heat as possible over a Bunsen flame (from which the air thermometer must be well shielded), a pair of forceps or tongs; a small copper heater (formed of a cylinder 2 cms. ($\frac{3}{4}$ in.) in diameter and 1·5 cms. ($\frac{1}{2}$ in.) thick) and a cloth.

Immerse the copper heater in the boiling water for 3 or 4 minutes. Remove it with the forceps, dry rapidly and wrap it in the folded calico. Balance it on (*a*) for 2 minutes. Note the distance to which the liquid falls in the tube as recorded by the scale.

Repeat with (2), (3) and (4). Take care that the liquid shall always rise to the same height in the tube before starting each observation.

(*C*) Measure 50 c.c. water into four small vessels. Immerse (1), (2), (3) and (4) in each respectively for five minutes. Drain off the water and squeeze the materials as dry as you can. Then repeat the test of relative heat conduction as in (*B*); compare the results in each case.

NOTE.—These observations can of necessity only show the relative conductivity of the *actual specimens* of material used for the purpose, and, however carefully selected, absolute uniformity of texture cannot be secured. The caution must be given, therefore, that a loosely-woven cotton may actually show less conductivity than closely-woven wool of the same weight. A specimen of closely-woven flannelette will, similarly, show less conductivity than a piece of coarse calico of the same weight. Probably the actual or relative conductivities of cotton, wool, etc., could only be found by a series of elaborate experiments on single fibres.

All organic substances are bad conductors of heat, *flannelette* and *calico* conduct heat relatively rapidly, absorb moisture readily and evaporate it quickly.

Wool is a poor conductor of heat; it absorbs moisture well and parts with it slowly. *Silk* holds an intermediate position.

The chilled sensation which results from "getting wet" is not from the coolness of the water, but is due to the loss

of heat attendant upon the prolonged evaporation of water from the clothing. It is characteristic of wool not to be wet by moisture but to allow it to pass through and evaporate. Cotton over wool becomes saturated and soon gives the odour of decay.

"Fine, smooth linen is dense, poor in air (42% air, 58% solid substance; when starched no air), has close contact with the skin and so feels cooler, conducts heat away more rapidly, has little or no air between it and the skin, becomes saturated with moisture and causes the concentration of the skin waste in the smallest space near the skin. It takes 30 times as long for a given quantity of air to pass through linen as through knitted wool. That cotton and linen bear washing by unskilled labour is the greatest argument for their use. Some modes of weaving may inclose as much air in a cotton or linen mesh as in wool, but the fibres lack elasticity and tend to become matted and saturated with moisture."—(*From Syllabus prepared by the Lake Placid Conference on Home Economics.*)

VIII.—**Test for the Hygroscopic Properties of various Materials.**

MATERIALS: *Calico; flannel; flannelette; water.*

APPARATUS: *Beakers; 100 c.c. measures.*

(*A*) Take three beakers (*a*), (*b*) and (*c*) and measure 50 c.c. of water into each.

Take pieces of calico, flannel and flannelette similar in size and quality to those used in (*B*). Soak these in (*a*), (*b*) and (*c*) for five minutes respectively, then remove them from the beakers and squeeze the water from them as thoroughly as possible into three separate receptacles, preferably c.c. measures.

Measure, and compare the amount of water absorbed by each material.

(*B*) Take three 100 c.c. measures (*a*), (*b*) and (*c*). Add to each 70 c.c. of cold water and immerse similar pieces of calico, flannel and flannelette for five minutes in them.

Remove the materials in turn from each c.c. measure; note carefully the amount of water each has absorbed as registered by the smaller quantity in the vessel.

Do the results confirm the opinion formed in (*A*).

(*C*) Place the damp pieces successively on the backs of the hands, and observe from the resulting sensations the relative rapidity of evaporation and loss of heat from the skin which follows this contact.

NOTE.—Distinction should be made between the two ways in which fabrics hold moisture; in (*a*) it may be retained in the interstices between the fibres of which they are composed, or in (*b*), it may be absorbed directly into the substance of the fibres. Moisture can only be accurately described as hygroscopic when present as described under (*b*). It can then be large in amount without causing any sensation of dampness and cannot be expelled by pressure, whereas, when it is retained in the form described in (*a*) it always imparts a sensation of wetness to the skin, and the amount present can be largely removed by squeezing. Wool and silk are hygroscopic in the true sense of the term, *i.e*, as described under (*b*). They absorb moisture readily into the substance of their fibres, yet no sensation of dampness is experienced when they are in contact with the skin. Cotton and linen come under the head of (*a*).

It must be remembered that water is a better conductor of heat than air, therefore one among other bad effects of damp clothes is the rapid removal of heat from the body. It was estimated by the late Professor Pettenkofer, of Munich, that the maximum hygroscopic properties of flannel were represented by 174 and the minimum by 111. While with linen the maximum was represented by 75 and the minimum by 41.

Wool, indeed, will absorb moisture until the material is sodden, which renders it unsuitable as an outer covering in heavy rain, when, on account of its impermeability, mackintosh has its special use. Woollen garments also require careful washing and are more expensive than those made of any other material except silk. In all other respects the use of porous woollen materials is to be recommended, especially for undergarments. Such clothing allows of free transpiration from the skin, which is kept warm on account of the slow evaporation through and from the covering, and risk of chill to the body is thus avoided.

Silk ranks next to wool in the scale of advantages, being warmer and more absorbent than cotton, but the unpleasing smell it soon acquires proves that it does not allow perspiration to evaporate freely and its cost precludes its general use.

Cotton materials are cheap and easy to wash, but unfortunately cotton is a good conductor of heat and a poor absorber of moisture. Cotton fabrics, therefore, especially when worn next to the skin, soon give rise to sensations of damp cold after active exercise; while linen not only shares in all the disadvantages of cotton, but attracts moisture and is much more costly. A further general defect in most silks, linens, and cottons lies in their web; they are too closely woven and so interfere with due ventilation of the skin.

By means of the tests to which flannelette is subjected (*pp.* 532-5), the pupils will realize that it is a cottonf abric. The sensation of soft warmth which it affords when in contact with the skin is the result of its loose texture, by which means air is freely entangled in its meshes, but this is very misleading as to its other characteristics, which are those of cotton.

Application of these principles must be made to foot gear. Circulation of air, opportunity for free ventilation and evaporation, as well as protection from too rapid loss of heat are all essentials to the healthy condition of the feet. Thread or cotton stockings conduct heat more rapidly from the feet than do woollen ones; and the thin, less elastic layer of material prevents circulation of the air. Leather is a non-conductor of heat when it forms a loose, soft covering, but it becomes a good conductor as it becomes more dense and impervious with "blacking" or filled with water.

IX.—The Relative Inflammability of Various Materials.

MATERIALS: *Calico; flannel; flannelette; alum; taper.*

APPARATUS: *Strong copper wire.*

(*A*) Take three lengths of strong copper wire and curve the tip of one end of each to form a hook.

Suspend respectively to each wire hook a strip of calico, of flannel, and of flannelette, these should measure the same size, about 7·5 × 2·5 cms. (3 × 1 inches).

Ignite each strip with a taper, and compare their relative inflammabilities.

(*B*) Prepare a weak solution of alum and immerse in it a piece of flannelette and a piece of cotton material similar in size and quality to the specimens used in (*A*). Dry the strips thoroughly, attach them to lengths of copper wire as in (*A*).

Ignite each specimen; how does the alum affect the property of inflammability in each case.

NOTE.—The density with which any given material is woven affects its inflammability. The specimens chosen for these tests should be selected therefore so far as possible of a similar density though of different materials. The great inflammability of flannelette has been the cause of so many deaths, especially of young children, that, as a result, the material is now treated chemically in the process of manufacture and can be purchased, as the "'A.L.' Flameless,"* at a very slight increase in cost.

X.—Tests for the Quality of Clothing.

MATERIALS: *Calico; flannel; flannelette; silk; mixed cotton and wool material, etc.; caustic soda; cupric hydrate; ammonia; magenta solution.*

APPARATUS: *Test tubes; glass rod; porcelain bowls; thermometer; sand-bath; Bunsen burner.*

(*A*) *Test for Wool in Clothing Materials.*

(1) Make about 300 c.c. of a 10% solution of caustic soda. CAUTION.—Be careful to employ forceps when handling this substance or any specimens which may have been immersed in its solution, otherwise painful burns will result.

Divide the solution into four test tubes (*a*), (*b*), (*c*) and (*d*). Steep in

(*a*) A piece of woollen material.
(*b*) A piece of cotton material.
(*c*) A piece of mixed cotton and wool.
(*d*) A piece of silk riband.

Boil the solution by standing the test tubes on a hot sand-bath over a Bunsen flame, stirring the contents of each with a glass rod.

Examine the result after a few minutes. Upon which material does the solution exercise its solvent properties?

(2) Collect scraps of a variety of materials, treat each as directed in (1). Classify them as (*a*), (*b*), (*c*) and (*d*), according as the results coincide with those obtained in (1).

* Sold by E. J. Arnold & Son. Ltd., Leeds.

Is this test of any service in detecting whether materials are mixtures of wool and silk or cotton or are composed of pure wool, silk or cotton?

(*B*) *Test for Silk in Clothing Materials.*

Divide 100 c.c. of concentrated hydrochloric acid into three small porcelain bowls (*a*), (*b*) and (*c*). Caution.—Use great care in handling this strong acid. Immerse in

(*a*) A small tuft of ravelled wool.
(*b*) A small tuft of tangled cotton.
(*c*) A small tuft of ravelled silk.

Examine the contents of the test tubes after half-an-hour. Can the tufts of threads be recovered from any of the bowls with a glass rod? In which of the three is there most evidence of dissolution?

Compare the results with those obtained in (*A*).

(*C*) *Test for Cotton in Clothing.*

(1) Prepare four small porcelain bowls (*a*), (*b*), (*c*) and (*d*). Place in

(*a*) A small piece of woollen material.
(*b*) A small piece of cotton material.
(*c*) A small piece of flannelette.
(*d*) A small piece of silk.

Take a bottle of cupric hydrate dissolved in ammonia and pour sufficient of this ammoniacal solution into each bowl to immerse its contents.

Stir these with a glass rod; in which bowl is the evidence of solution most marked.

Does the result in (*c*) confirm the observations made on flannelette in *pp.* 532-5 and *p.* 536.

(2) Prepare a large beaker of a weak, warm solution of magenta. Immerse in it specimens of each of the materials used in (1) for half-an-hour. Maintain an even temperature by standing the beaker on a hot sand-bath. Remove the specimens and then rinse them in cold water.

In which is the dye not washed out?

NOTE.—Wool and silk dissolve entirely in strong solutions of caustic soda or potash; silk is also dissolved by concentrated hydrochloric acid, which does not dissolve wool. Some forms of cellulose dissolve readily in sulphuric acid, but cotton is most easily separated from wool or silk by an ammoniacal solution of cupric hydrate. Cotton or linen part with a dye applied as in (*c*) (2), when well rinsed, but wool or silk retain it.

Much interest will be added to this study if specimens of each kind of fibre (wool, silk, linen and cotton), are shown under the microscope. By this means the very different character of their respective structures will be clearly demonstrated, and will contribute to a more intelligent realization of the significance of the foregoing and the following experiments.

XI.—Method of Washing Clothes.

MATERIALS: *Small, soiled kitchen-cloths or stockings; pieces of calico; dirty flannel; yellow soap; castile soap; washing soda; washing powder; alcohol; rain-water.*

APPARATUS: *Bowls; beaker; test tubes; 3 flasks with stoppers; graduated burette; balance; wooden spoon; Bunsen burner.*

(*A*) (1) Take three, small, soiled kitchen-cloths or three, soiled, cotton stockings, label them (*a*), (*b*), and (*c*), or distinguish each specimen by a coloured thread. Wash each as follows:—

Plunge (*a*) into a bowl of boiling water; rub it well with yellow soap, wring it well. Rinse it free from soap in cool water, wring out all the moisture possible and lay it aside.

(2) Prepare a bowl of tepid water, and proceed to treat (*b*) in every respect as (*a*); lay it also aside.

(3) Set (*c*) to soak in a bowl of tepid, soapy water for one hour; meanwhile prepare some soap solution by shaving about 56 grams (2 oz.) good, hard soap into a pan and pouring upon it 2 litres (2 qts.) of boiling water; if necessary, boil the mixture until all the soap is dissolved, then beat it to a lather with a wooden spoon, and transfer a portion of it into a large bowl; add more boiling water to fill the bowl.

Remove (*c*) from the vessel in which it has been soaking, and plunge it into the bowl of soap-suds, rub it well and wring. If very greasy and dirty, place it in a pan with some cold water and soap-solution and boil all together for some minutes. Conclude, in either case, by rinsing well in several relays of tepid water, until the water so used remains clear; then wring out all the moisture possible.

Compare the cleanliness of each specimen. What conclusions are to be drawn respecting the right method of cleansing garments?

NOTE.—The "dirt" in clothes consists of inorganic and organic matter (such as road dust with all its unsavoury constituents, soot and sweat), which are present in the form of dried or greasy particles. The first object of washing garments is to dissolve and expel these particles, therefore water is used because of its high solvent powers, especially when hot. Even these, however, are insufficient to remove oily dirt, hence soap becomes an indispensable agent in domestic cleansing processes. It is the opinion of recent investigators that the explanation of the value of soap as a cleansing agent is to found in the phenomena associated with a low surface tension.

(4) (i.) Take two pieces of white calico (*a*) and (*b*) about 15 × 15 cms. (6 × 6 inches).

Weigh out equal quantities (*c*) and (*d*) of washing soda, (1 gram or ¾ drachm) will suffice.

Dissolve (*c*) in 250 c.c. (1 pint) of boiling water in a beaker and immerse (*a*).

Wring (*b*) out in warm water, and deposit (*d*) in one lump on its surface.

Remove (*a*) from the solution after one hour; rinse thoroughly, dry, and compare its appearance with (*b*) from which any undissolved soda must be removed.

In both cases some discolouration will be observed. Dry and pass a hot iron over both specimens. Observe the scorching which occurs in (*b*), from which the soda has not been removed by rinsing.

(ii.) Make a strong solution of some washing powder in a beaker. Immerse (*a*) in the liquid and boil for 15 minutes. Remove, and dry quickly. What change has taken place in its colour? Compare with an unwashed piece of similar material.

NOTE.—Soda must be used with great discretion and invariably well rinsed out from all fabrics, because of its power of discolouring white materials and because of its destructive action on animal fibres such as wool and silk. There is more than one reason for the practice of adding soda, or some other alkaline compound, to water for cleansing purposes. Neither dirt nor soap dissolves readily in hard water, the latter forms a curdy substance and requires to be used in much larger quantities than in soft water to gain the same result (*see* (*C*), (*D*), *pp*. 542-3).

(*B*) *Methods of Washing Woollen Materials.*

Take three pieces of dirty flannel of equal size and quality, (*a*), (*b*), (*c*).

Wash (*a*) in very hot water, rubbing it with hard soap; wring well, rinse and dry it very quickly before a fire or close to a Bunsen burner.

Immerse (*b*) in boiling water with soda. Maintain this temperature for five minutes. What is the result?

Wash (*c*) in tepid water with soap-jelly, shake well; rinse, and dry moderately quickly, not too near the source of heat.

When dry, compare the size, texture and elasticity of each specimen of flannel.

NOTE.—The first method of washing will leave the flannel in (*a*) thick, hard and badly shrunk; the second will almost entirely destroy the fabric as in (*A*); the third specimen will be soft, elastic, white, clean and unshrunken. When a woollen fabric is rubbed or caused to expand by the application of great heat and subsequently to contract by cold, the position of its component fibres is changed.

Remember that a fibre of wool consists of a number of sheaths (probably 1,200 to 1 cm. or 3,000 to 1 inch) with serrated outer edges, these hook one into the other as the fibres shift and slip by one another, and as they cannot be subsequently withdrawn the material "shrinks."

A poor quality of common soap thickens flannels, and if *rubbed* in to the material the results are intensified.

Soda, which is a strong alkaline compound, makes wool hard and restores its natural colour, which has been removed in white wool by bleaching with an acid, sulphur dioxide gas, or concealed by dyeing. Most colours, in fact, are more soluble in water than in saline solutions, hence the practice of adding salt to water in which black or delicately coloured articles are to be rinsed, in order to preserve their colours. If woollen materials be dried quickly, even after the most careful washing, they shrink badly for the reason just given; they must never be placed so near a source of heat as to "steam." On the other hand if woollens be left to dry too slowly they become hard and lose their elasticity. Great care and discretion must be used throughout the process, for if shrunk, woollens are an economic loss, and this condition also destroys their hygienic value by reducing them to a hard, impervious felt.

(*C*) (1) Repeat VI.—"WATER," III. (*F*) (1), *pp*. 65, 66, but substitute rain water for sewage water in (*c*). Compare the residue in each case.

(2) Take three test tubes (*a*), (*b*), (*c*). Place in—

(*a*) 10 c.c. tap water;

(*b*) 10 c.c. rain water;

(*c*) 10 c.c. water which has been boiled for half an hour.

Proceed as follows to test their relative soap-destroying capacity by Clark's Soap Test:—Make a standard soap solution consisting of 1 gram (15 grains) Castile soap, scraped into fine shavings and dissolved in 100 c.c. (3 oz.) of a mixture composed of $\frac{2}{3}$ alcohol and $\frac{1}{3}$ water. Filter the solution if it is not quite clear, and store it in a stoppered bottle.

Draw up some of the solution into a pipette and add a drop to (*a*); close the mouth of the test tube with a rubber cork (or the thumb) and shake the contents vigorously. Continue this procedure until a lather is obtained which lasts 5 minutes. Keep careful count of the number of drops used to effect this result.

(3) Repeat the process with (*b*) and (*c*).

The relative hardness, or soap-destroying capacity of these waters, will be in proportion to the number of drops added to each respectively before a good lather is obtained.

(*D*) Determine the *Total* hardness of water more accurately as follows:—

Prepare three flasks (*a*), (*b*) and (*c*), with stoppers. Place in them 70 c.c. (3 oz.) of each kind of water used in (*C*).

Run in, from a graduated burette, a sufficient quantity of the Standard Soap Solution (of which 1 c.c. equals 1° of hardness) to produce a lather which remains unbroken for 5 minutes after shaking the contents of the flask.

NOTE.—If, for example, 7·5 c.c. of the soap solution are required to produce such a lather, the hardness of this specimen of water is 6·5° (1 c.c. of the solution is required to produce a lather even in distilled water). The 6·5° means that there are 6·5 grains of calcium carbonate in 4·5 litres (1 gallon) of water.

The commonest mineral constituent of water is calcium carbonate (chalk), or calcium sulphate (gypsum), and the greater or less amount present of either or both of these salts causes a water to be classed as "hard" or "soft." Other inorganic salts, such as magnesium, aluminium or iron, are also usually present, but in association with either calcium carbonate or sulphate.

Waters containing carbonates can be readily softened by precipitating a considerable amount of the salts by boiling, by the use of soap, or by the addition of a sufficient quantity of lime-water. Hardness caused by carbonates is therefore called *temporary*. It is practically impossible to soften water impregnated with sulphates by boiling, but the salt is partially precipitated by the addition of washing soda. Hardness so caused is consequently described as *permanent*.

No lather can form in hard water until all the chalk it contains has combined with the soap to form a *curd*, which is practically a new body consisting of the precipitate of the insoluble salts present. This curd does not possess the properties of soap, so that, as far as cleaning purposes are concerned, this amount of soap is lost; whereas in the case of rain water, where very little matter is held in solution, the whole of the soap is available.

If each $4\frac{1}{2}$ litres (1 gallon) of water have only 1° of hardness, an exceptionally low degree, ·4 gram (8 or 9 grains) of soap would be wasted before the desired result is attained. If there be 20° of hardness (a by no means unusual amount), a slight calculation will afford an estimate of the annual expenditure on wasted soap which takes place in each household where hard water only is available.

When hard water is boiled, the carbon dioxide dissolved in the water is driven off, and as the calcium carbonate is held in solution by this gas it is precipitated in an insoluble form when all the gas has been expelled. The "crust" in boilers and the "fur" in kettles consists of lime salts held in solution until precipitated by boiling. When lime is added in sufficient quantities to hard water, it unites with the carbon dioxide present in the water and forms an insoluble body, carbonate of lime. In the course of its precipitation it also carries down, in an insoluble form, the carbonate of lime already present in the water, because there is no more carbon dioxide gas to hold it in solution.

XXIII.—CLEANLINESS.

The skin. The nails. The teeth and mouth. The hair. Clothing. Development of micro-organisms. Principles of disinfection.

I.—The Skin.

MATERIALS: *Nutrient gelatine; soap; nail brush; towel; water.*

APPARATUS: *Petrie dishes; small, sharp scissors; air-oven; retort stand; Bunsen burner.*

(*A*) Melt a tube of nutrient gelatine and pour its content into four sterile Petrie dishes (*a*), (*b*), (*c*), and (*d*). Replace the covers and allow the gelatine to set. Remove the cover from (*a*) and dab the fingers of the right hand firmly all over the surface of the gelatine, but do not break it by undue violence. Replace the cover, label the dish and set it aside in a warm dark place (37° C.; 99° F.) for two days.

(*B*) Wash the hands with soap and cold water, dry them, and repeat with (*b*) the procedure directed in (*a*).

(*C*) Scrub the hands thoroughly for at least five, but preferably for ten, minutes with very hot water, soap and a nail brush which has been boiled for at least 20 minutes. Rinse the hands in abundance of hot water previously boiled and cooled until bearable to the hands. Dry them on a cloth sterilized for 2 hours in the hot air-oven. Repeat with (*c*) what has been carried on with (*a*) and (*b*).

Examine the three cultures after two days. What lesson does their appearance teach as to the general condition of the skin, and the results of ordinary careless methods of washing the hands, as contrasted with a thorough cleansing process.

NOTE.—A very abundant growth of micro-organisms will take place in (*a*), a less luxuriant development will be seen in (*b*), (*c*) may be quite sterile or the number of colonies will be insignificant.

Experiments by Koch and others indicate that soap, especially when made with potash (soft soap), possesses a certain antiseptic as well as cleansing power, though the soap used should be of a good quality and must be employed with very hot water.

Fresh air, soap, water, and sunshine are to be strongly advocated as domestic germicides.

(*D*) Snip some tiny fragments from the epidermis where it is thickened, say on the fore-finger; use a small pair of very sharp scissors which have just been sterilized (*see* II.); *no blood must be drawn.* Or collect a few scrapings of skin from about the roots of the finger nails.

Shake these from the scissors on to the surface of (*d*) and immediately replace the cover of the dish.

Keep as directed for (*a*), (*b*), and (*c*).

Notice from the results obtained to what a limited degree prolonged washing and scrubbing of the hands serves to cleanse the crevices of the skin.

NOTE.—Greater or less results in the forms of colonies of micro-organisms will be obtained and will demonstrate that ordinary methods of washing, even when vigorously practised, only affect the surface cleanliness of the body.

Where these are neglected, the state of personal uncleanliness becomes a source of low health to the subject and of risk or offence to his neighbours.

Bacteria are mostly found in the superficial layer of dirt, sweat, and dead epithelial scales on the surface of the body, but some of the number permeate the minute interstices between the epithelial scales of the skin to some slight depth, they are also abundantly present in the inequalities of the nails or in other lurking places such as the hair.

To mop over the surface of the body with even large volumes of water is futile in respect of real cleansing of the skin. Essential agents for this purpose are *soap* to dissolve the oily dirt, *vigorous scrubbing* and rubbing to remove the dead, greasy organic matter and to permeate as thoroughly as possible the folds and crevices of the skin, and *hot water*, the solvent properties of which are indispensable. (*cf.* "*The Organs of Excretion*," I. (*E*) (*H*), *pp.* 201, 2).

II.—The Nails.

MATERIALS: *Nutrient gelatine; oil; soap; nail brush.*

APPARATUS: *Petrie dishes: thermometer; knife or small pointed scissors; Bunsen burner.*

Prepare two sterilized Petrie dishes (*a*) and (*b*). To each add a small quantity of slightly warmed nutrient gelatine.

Sterilize the blade of a knife or of a small pair of pointed scissors by passing them rapidly to and fro through a Bunsen flame, or by boiling them for some minutes in water, or by dipping them into a small quantity of boiling oil.

Use the instrument to collect any matter accumulated beneath the finger nails of one hand and scatter it on the surface of (*a*).

Thoroughly wash the hands, using hot water, soap and a nail brush as in (I.) (*C*); again sterilize the instrument used, and repeat the above process with (*b*), making the culture from the nails of the other hand.

Keep both dishes in a dark place at a temperature of about 37° C. (99° F.) and watch the results.

NOTE.—Impress the unpleasant and possibly dangerous results of handling food, or the utensils in which food is cooked or served, with dirty, unwashed hands.

Tubercle bacilli have been proved to be occasionally present in the dirt beneath finger nails, and there is good reason to believe that certain acute glandular diseases from which children suffer may be the direct result of disease germs, present in the dust of rooms or streets, with which a child's hand has come in contact. Fingers are constantly carried to the mouth or nose, so that slight lesions in the mucous membranes of either organ would permit such germs to penetrate into the deeper tissues of the body.

It is of great importance to realize the fact that living dirt is not confined to exposed portions of the body.

Constant care is necessary to maintain scrupulous cleanliness of the *whole* person, to which end every part of the body should be washed with hot water and soap at least once or twice weekly, preferably each day, and then well rubbed with a rough towel to remove dead skin, the secretions of the sebaceous and sweat glands and other matters liable to be retained in the folds and interstices of the skin.

III.—The Teeth and the Mouth.

MATERIALS: *Cotton wool; nutrient gelatine; water.*

APPARATUS: *Petrie dishes; test tubes; five* 200 *c.c. flasks; watch glass; pipette; platinum wire; air-oven; Bunsen burner.*

(*A*) *The Teeth.*

Take a test tube half full of nutrient gelatine. Melt the contents, and support the tube at such an angle that the gelatine will solidify in a slanting position, which gives a larger surface for the form of culture, known as a "streak culture," to be now made.

Sterilize the loop of platinum wire used in "GENERAL CONSTITUENTS OF THE BODY," V., *page* 176, by heating it to redness in a Bunsen flame; allow it 20 seconds in which to cool, then quickly introduce it into the mouth, rapidly scrape the surface of the front teeth, remove the plug of sterilized wool from the mouth of the tube, draw the platinum wire lightly but firmly over the sloping surface of the gelatine (*i.e.*, "streak it"); pass the plug of wool through a Bunsen flame to resterilize it, close the mouth of the tube and set it aside under conditions similar to those prescribed in I. and II.

(*B*) *The Mouth* (after Dr. Mervyn Gordon and Dr. F. W. Andrews).

Take 5 small flasks, each to hold 200 c.c.; label them (*a*), (*b*), (*c*), (*d*), (*e*).

Put 99 c.c. distilled water into (*a*), and 90 c.c. into each of the other four. Plug the neck of each with cotton wool, heat them for half an hour in the hot air-oven, and allow them to cool.

Sterilize a watch glass (*page* 42) and collect in it some saliva from the mouth.

Sterilize a pipette and by its means transfer exactly 1 c.c. of the saliva from the watch glass to (*a*). Its contents represent a dilute solution of saliva 1 in 100.

*Shake (*a*) thoroughly for some minutes to ensure an equable distribution of the saliva and its contained bacteria, then, with a sterile pipette, transfer 10 c.c. of its contents to (*b*). The flask will then contain a saliva solution of 1 in 1,000.

Repeat from* with (*c*), (*d*) and (*e*), that is, transfer 10 c.c. of the contents of (*b*) to (*c*), then 10 c.c. of (*c*) to (*d*), and finally 10 c.c. of (*d*) to (*e*).

Flask (*e*) will thus contain a million-fold dilution of the saliva in sterile water, and each c.c. of its contents will contain approximately the bacteria present in the millionth part of a c.c. of the original saliva.

Melt a tube of nutrient gelatine, and when it has cooled to a temperature of 45° C. (113° F.) add to it, by means of a sterilized pipette, 1 c.c. of the dilute saliva solution from (*e*).

Mix the contents of the tube by quick rotation, but with care, and pour them into a sterile Petrie dish before the gelatine has begun to set.

Set the dish aside for two days as directed in I. (*A*).

NOTE.—It is probable that quite a hundred colonies of micro-organisms will develop upon the surface of the gelatine, indicating one million times that number in each cubic centimetre of saliva. Even this figure is far below the truth, according to Dr. Andrews, who points out that large numbers of the mouth bacteria will not grow in this form of culture media.

IV.—The Hair.

Pull two or three hairs from the head; prepare a sterilized Petrie dish, pour a layer of sterilized nutrient gelatine over the bottom and, just before it solidifies, snip the hairs into short lengths over its surface, using scissors sterilized by passing the points several times through the flame of a Bunsen burner. Cover immediately, and keep the dish in a warm (37·5° C·; 98° F.) dark place.

Examine after two days and subsequently daily, for any change in the appearance of the gelatine.

Does the result suggest the importance of attention to the washing and brushing of the hair?

NOTE.—A considerable crop of moulds will probably develop from the dust on the hair; two or three minute, shiny, white or yellow specks may also indicate the presence of colonies of bacteria, though, unless under conditions of great personal uncleanliness, they should be very few in number and of unimportant character.

The necessity for frequent cleansing of the hair will nevertheless be quite obvious, and the facility with which ringworm and head lice grow and develop will be more readily comprehended after this demonstration upon hair, pulled from a presumably well kept head.

V.—The Clothing.

MATERIALS: *Cotton wool; large potatoes; water.*

APPARATUS: *Test tubes; cork-borer; knife; hand lens; Bunsen burner.*

(*A*) *Preparation of Potato for Culture Purposes.*

Method I.

(1) Select and wash two large, sound potatoes. Cut off the ends, and then cut out cylinders of potato by means of a large cork-borer, previously sterilized; the cylinders should be a little smaller than the tubes in which they are to be placed. Handle the potatoes as much as possible under water to prevent darkening of the surface.

Slice each cylinder diagonally into two wedge-like halves, and keep them in running water for at least 12 hours to wash out the phosphoric acid and render their reaction neutral. Keep all the cut pieces of potato in water.

(2) Provide the requisite number of large test tubes, (*a*), (*b*), (*c*); place *absorbent* cotton wool at the bottom of each tube to the depth of 2·5 cms. (1 inch), plug in the usual way with ordinary cotton wool, and sterilize the tubes for one hour at a temperature of 160° C. (320° F.).

(3) Place a wedge of prepared potato in each test tube, cover the potato with distilled water, replace the plugs of wool, and sterilize by raising the temperature of the water to boiling point for at least 30 minutes on three successive days, proceed as directed in (*C*) (3)

(*B*) *Method* II.

(1) Prepare three test tubes (*a*), (*b*) and (*c*).

Cut three slices from the interior of a healthy potato, each to measure 1 cm. × 1 cm. × 3 cms. (about $\frac{2}{5}$ in. × $\frac{2}{5}$ in. × $1\frac{1}{4}$ in.), place one of these in each test tube, cover them with water, and plug the tubes *loosely* with sterilized cotton wool.

(2) Raise the water in the tubes to boiling point for 15 minutes on three successive days.

(3) After the boiling process is complete on the third day remove the plugs, pour off the water, quickly replace the plugs and proceed as follows :—

(*C*) (1) Set (*a*) aside, untouched, and in the dark, for two or three days at a temperature of 20° to 25° C. (68° to 77° F.).

(2) Remove the potato from (*b*) with a pair of sterilized forceps and rub one of the long sides upon the sole of one boot; rapidly replace the potato in the test tube and pass the plug of wool through a Bunsen flame before closing the mouth.

Set (*b*) aside with (*a*) for future examination.

(3) Remove the potato from (*c*) with sterilized forceps and rub one of the long sides upon the sleeve or some other exposed portion of a well-worn garment. Proceed in all respects as with (*b*).

Compare the appearance of (*a*), (*b*) and (*c*) after 2, 3 and 4 days.

NOTE.—The plugs of cotton wool should be inserted in such a way as to allow of the free passage of steam during the thrice repeated boiling of the water, but must not be wetted by the water itself.

If this accident occur the wet wool must be rejected, a fresh plug must be inserted and the sterilizing process must be begun afresh.

Observations on the results of the experiment must be carried on for several days, as very possibly the cultures will take longer to develop in some cases than in others. Always insist that a hand lens be used when examining the results of these tests.

Refer to the NOTE, *page* 54, in order to remind pupils that the growth of moulds must be distinguished from the appearance which characterizes bacteria. This resembles smooth spots of slime, yellowish-grey or coloured. Moulds are frequently luxuriant when no bacteria are present. The following series of experiments will illustrate elementary facts connected with the nature and sources of bacteria, to which reference has been already made in XX.—"*Methods of Food Preservation*," (*A*) (*B*), *pp*. 451—453.

VI.—The Development of Micro-Organisms.

MATERIALS: *Straw from farm-yard or stable; hay; water.*

APPARATUS: *Test tubes; large glass jar; thermometer; knife; retort stand; Bunsen burner.*

(*A*) Take a handful of straw from a stable or farm-yard. Chop it into convenient lengths and put a thick layer at the bottom of a large glass jar (a 2 lb. glass jam or fruit jar).

Fill the jar three-quarters full of warm water (25° C., 77° F.) and stand it in a cupboard or other convenient place where the temperature is about 21° C. (70° F.), and as equable as can be arranged.

Watch the series of changes which take place during four or five days, and make notes of the order of their appearance. Do they afford evidence

(1) That micro-organisms develop rapidly in the presence of warmth, moisture and organic matter? ("PHENOMENA OF LIFE," II., *pp.* 18—20.)

(2) That they exhibit the vital characteristics of assimilation of nutriment, respiration, excretion, reproduction, and putrefaction. ("CHARACTERISTICS OF LIFE," IV., V., X., *pp.*, 21, 27, 35.)

NOTE.—A slight change to a darker colour and a musty smell will be noticed at a very early stage of the experiment, which will intensify perceptibly during the first 48 hours. On the third day a thin scum will form on the surface of the water, and the active movement of minute particles can be seen in the infusion, while the odour will become offensive. On the fourth day the scum will be much thicker and bubbles of gas will appear in and on it. If a microscope be available, examination of a speck of the scum under a high-power lens will reveal that it is composed of myriads of micro-organisms, the germs of which were present on the dry straw. The series of changes which have have taken place in the infusion are the result of their growth, multiplication, and activity and subsequent destruction.

(*B*) *Conditions favourable to the growth of Micro-Organisms.*

Take four test tubes (*a*), (*b*), (*c*), (*d*).

Place a little dry, chopped hay in each; set (*a*) aside in a warm, dry place.

Pour sufficient warm water (25° C.; 77° F.) into (*b*), (*c*), and (*d*), to cover the hay.

Keep (*b*) in the light, if possible in sunshine if available.

Set (*c*) aside in a dark, cool place.

Set (*d*) aside in a dark and warm place.

Keep each specimen for three days before any observations or comparisons are made.

Record in each case the influence of moisture, temperature, or light upon hay infusion and compare with XX.—"METHODS OF FOOD PRESERVATION" (*A*), (*B*), *page* 454.

NOTE.—All bacteria do not thrive or even develop under these artificial conditions, especially as details of cultivation vary as widely as in the case of other vegetable seeds. Nevertheless, if care be taken to use sterilized apparàtus and to maintain those conditions of warmth, darkness, soil and moisture that are most generally favourable to the growth of micro-organisms, it will be possible, even with the naked eye, to distinguish between colonies of different kinds, because, when seen in masses they differ in size, shape, colour, and consistency.

A complete course of practical bacteriology is unnecessary and would be impossible for the general public, but most of the essential truths concerning the work of micro-organisms, as well as the general principles of sterilization and disinfection, can be illustrated by the series of observations with the naked eye suggested in this book. If the pupils have acquired the art of using the microscope, or can proceed to more advanced work, the foundations laid by the "naked eye bacteriology" previously practised will add to the interest and intelligence of their studies.

"Plate cultures" are made in Petrie dishes of various diameters where a large surface is required, or where a study is to be made of individual colonies under a powerful hand lens or a low-power microscope. When it is desired to study bacterial growth in the depth of the medium, test tubes are employed. The medium contained in the tubes is inoculated with the bacteria by one of the three methods of culture, known respectively as the "streak," the "surface," or the "stab," according to the mode in which the inoculating instrument is brought in contact with the medium.

Nutrient gelatine is, on the whole, the most favourable solid culture medium for elementary students, though as it melts easily, precautions must be adopted to protect it from the sun's rays or from other sources of great heat.

Reference must be made to the minute size of bacteria; this can only be illustrated by the fact that their dimensions can be estimated only in micro-millimetres. A micro-millimetre or "micron" may be defined as the thousandth part of a millimetre. As a millimetre corresponds to $\frac{1}{25}$ of an inch, a micro-millimetre represents $\frac{1}{25000}$ of an inch, (this measurement is usually designated by the Greek letter λ).

The little, shiny spots which develop upon the surface of a gelatine culture, technically known as "colonies," consist

each of hundreds or thousands of micro-organisms reproduced with inconceivable rapidity by the single individual of that species which became fixed at that point when the gelatine or other culture medium cooled. Under a high-power microscope, many differences in the appearance and mode of growth become visible in these colonies. Some bacteria are colourless, others are coloured, some are smooth, some have jagged or fringed edges, while others cause the gelatine to liquefy in their immediate neighbourhood.

The terms "germs" and "bacteria" are applied to a whole class of micro-organisms, which are divided into two main groups of *lower* and *higher bacteria*. The former group has three chief forms, (I.) The *Cocci* or spherical bacteria, (II.) The *Bacilli* or rod-shaped bacteria, and (III.) The *Spirilli* or spiral thread bacteria. Numerous sub-divisions occur in each group, but differences are often so slight that expert knowledge is necessary to distinguish harmful from harmless species.

Reproduction or multiplication is usually effected by the process of division known as "fission," but under some circumstances some bacteria reproduce also by "spores." These tiny, rounded masses or spores form within the parent body, increase in size and finally escape from their confinement, but at the cost of the parent's own existence. In spite of their infinitesimal dimensions these spores can resist far more adverse conditions than bacteria, such as the temperature of boiling water, a fact due to the possession of an impenetrable kind of capsule, impervious to most chemical agents and to heat. When the environment of the spore is suitable for active life, this thick coat ruptures and the spore grows into a bacillus.

One bacterium, multiplying by fission at the rate of one per half-hour, could have 17 millions of descendants at the end of 24 hours, and Professor Conn has calculated that if the process continued unchecked the ocean would be filled solidly full in five days.

Gigantic results may be and are brought about by the offspring of even one micro-organism in spite of the restraint put upon the process of multiplication by numerous environmental conditions. This is seen in their marvellous ability to destroy rubbish and refuse, which would otherwise cumber the surface of the earth, and in the prosperity of the tanning, indigo, and other industries which depend upon their agency.

The rapidity with which an epidemic of cholera or diarrhœa will spread, when one infectious germ gains access to a supply of water or milk, as well as the perpetuation of phthisis, illustrate this same characteristic in another sphere.

The primary function of yeasts and bacteria is benign, their activities become malign chiefly when, by ignorance or mismanagement, they are not restricted to their proper sphere of action. It is believed that bacteria are omnipresent except at very high altitudes, in mid-ocean, in the air exhaled from healthy lungs, in the deeper layers of the soil, in water drawn from great depths, in the internal fluids such as the blood and lymph, or in the tissues and secretions of healthy, normal animals and plants.

Bacteria always adhere to moist surfaces, hence expired air is practically free from these organisms; for though many thousands may be inspired, they are retained by the moist mucous membrane of the mouth, nose, throat and bronchial tubes. For this reason the breath of a consumptive is free from tubercle bacilli, though these micro-organisms are expelled with the sputum in particles of moisture when coughing.

Bacteria are broadly grouped according to their habitat into *Saprophytic* (*see "Methods of Food Preservation," page* 452) and *Parasitic.*

The vast majority of bacteria belong to the first group, which live on dead animal or vegetable matter. Generally speaking it is these which contribute most to the benefit of man, through the invaluable services they render in the processes of fermentation, decomposition, nutrification, etc. The parasitic group is much smaller, they thrive chiefly *in* the living plant or animal, upon the waste products of living cells and, more rarely, upon these after death. The various disease-producing organisms are parasitic. Some species of bacteria are, however, both saprophytic and parasitic. Bacteria grow poorly at temperatures below 10° C. (50° F.) or above 40° C. (104° F.), though there are some species which flourish at 68° C. (154° F.). Parasitic bacteria do best at the temperature of their host, saprophytic bacteria thrive at summer heat 25° C. (77° F.). Several species of phosphorescent bacteria grow and emit light at 0° C. (32° F.), while those of another group multiply at or about freezing point. Again, certain non-pathogenic species grow at such high temperatures that they are designated *thermophilous.*

Cold arrests the vitality of but does not kill bacteria, whereas high temperatures weaken their growth and finally destroy them. A few hours exposure to direct sun-light usually destroys vegetating bacteria, and the destruction is specially active in the presence of air. Some pathogenic bacteria, *e.g.*, the tubercle bacillus, are weakened by mere exposure to daylight.

About fifty species of bacteria, described as *anaerobic*, thrive in the absence of air; their products are usually most offensive, as they are powerful agents in the chemical changes known as putrefaction. This work of breaking down chemical compounds is necessitated in order that they may get oxygen in the form required for the maintenance of their life processes. A few of these anaerobic bacteria, such as the bacilli of tetanus (lockjaw) are pathogenic.

The products of bacterial activity are known as enzymes or ferments. Fermentation consists essentially of a process of breaking down complex bodies into simpler ones. Each ferment is capable of producing a variety of still unexplained chemical changes, and each is characterized by the capacity for bringing about effects out of all proportion to to the amount of matter required to produce them.

Though always the product of living agents, these ferments or *enzymes*, whether benign or toxic in their action, are divided by Prof. Schäfer, F.R.S., into 2 groups :—

(1) In the first of these the action is *direct*, the chemical changes involved in the process occur only in the presence of the organism of whose activity they are the out-come. These are known as *organized* ferments and they are the product of a species of bacteria, or of vegetable cells closely allied to bacteria.

(2) In the second group the action is described as *indirect*, because here the changes are the result of the presence of a soluble material secreted by a cell, but acting apart from it. This soluble substance is described as an enzyme, or as an *unorganized soluble ferment*. The *diastase* which occurs in malt is a common example of such an enzyme, so also are the digestive agents in the human body, such as ptyalin, pepsin, etc. (" *Characteristics of Life*," IV., Note *page* 27. " *Process of Metabolism*," I. (*A*) (6), *pp*. 188-9; II. (*A*) Note *p*. 191; III. (*A*) Note *pp*. 193-196).

None, however, of the unorganized ferments are capable of reproduction, nor do they show any sign that they consist of organized bodies like yeast. This constitutes a character-

istic distinction between the two groups; organized ferments have form and are living and insoluble, whereas unorganized ferments are formless, non-living and soluble.

An elementary study of the conditions which favour the growth of bacteria should include some application of this knowledge to the means by which their vitality and virulence can be checked as well as promoted.

The influence of temperature, moisture and sunlight upon vitality should, of course, be well understood by pupils who have performed the various experiments suggested throughout the book in this connection. A few illustrations are given in VII. of some of the methods employed for the destruction of pathogenic bacteria, generally spoken of as *Disinfection*.

Reliance may be placed upon two groups of disinfecting agents, if properly employed:—

(1) The use of heat in various forms, preferably moist.

(2) The use of chemical bodies in various forms, by suitable means, and in sufficient strength.

The following experiments are designed, therefore, to show why moist heat is more destructive to micro-organisms than dry heat, and to point out the precautions which should be observed in the use of disinfectants.

VII.—The Principles of Disinfection.

Materials: *Infusion of hay; compressed yeast; treacle; nutrient gelatine; egg albumin solution; flannel; cotton wool; muslin or filter paper; ice; perchloride of mercury; carbolic acid; chloride of lime.*

Apparatus: *Test tubes; beakers; c.c. measures; flasks; glass cylinders; Petrie dishes; thermometer; clinical thermometer; platinum wire or large needle; rubber corks; wood or card screen; covered pan; retort stand; air-oven; Bunsen burner.*

(*A*) *By Heat.*

(1) Prepare two test tubes (*a*) and (*b*) as directed in II.

Dip a sterilized platinum wire or large needle into the scum on the surface of an infusion of hay. (This must be made from a small quantity of chopped hay covered with water, kept in a warm, dark place for three days before it is wanted).

Remove the plug of wool from (*a*), draw the wire across the sloping surface of the nutrient gelatine, pass the plug through the flame of a Bunsen burner, then immediately close the mouth of the tube and set it aside in a warm, dark place for five days.

Repeat with (*b*), but before setting it aside with (*a*), support it in a covered pan in which the depth of the water is not more than half the height of the tube. Maintain the water at 100° C. (212° F.) for at least 15 minutes, plug the tube while the water is still boiling, and keep it under the same conditions as (*a*).

(2) Take two test tubes (*a*) and (*b*) and place in each 25 c.c. of a weak solution of treacle and water (*page* 22) at a temperature of 35° C. (95° F.). Sprinkle a few crumbs of compressed yeast on the surface of the solution, plug (*a*) with cotton wool and set aside in a warm, dark place.

Boil (*b*) as directed in (1); plug, and set aside with (*a*).

Examine both tubes for any signs of activity in the yeast after a few hours.

NOTE.—If carefully carried out, there should be, as a result of these experiments, a luxuriant growth in each tube labelled (*a*), while the (*b*) tubes should have had their contents sterilized by exposure to a high temperature. Such sterilization must, however, be sufficiently prolonged and carried on at a sufficiently high temperature to ensure that the micro-organisms are killed. If the first attempt fail to obtain these results repeat the experiment, observing greater care in the sterilization of the tube, gelatine, instrument and wool used, and maintaining the high temperature for a longer period.

(*B*) *To Illustrate the Principle of Disinfection with Saturated Steam.*

(1) Take three strips of flannel 7·5 × 5 cms. (3 × 2 ins.) (*a*), (*b*) and (*c*).

Dry (*a*) very thoroughly before a fire or in the air-oven, and allow it to cool. Dip (*c*) in cold water and wring it out as dry as possible.

(2) Take the temperature of your breath with a clinical thermometer by breathing upon the bulb of the instrument for 5 minutes.

Note the record (about 37·4° C.; 99·2° F.). Roll the thermometer in the well-dried strip of flannel (*a*). Hold the end of the roll which covers the bulb of the thermometer in the mouth, inspire through the nostrils, close them with the fingers and expire through the mouth. Repeat this process for five minutes.

Remove (*a*), and record the temperature registered by the thermometer. Shake down the mercury.

(3) Repeat (2), but roll the thermometer in (*b*), which has been exposed merely to the ordinary temperature and humidity of the room.

(4) Repeat (2), but roll the thermometer in (*c*). Then compare the records of temperature in each experiment.

NOTE.—Dr. Parsons found when making this experiment that if the temperature of the breath were 37·4° C. (99·2° F.) the temperature recorded in (2) would be about 43° C. (110° F.). In (3) the temperature would rise above that of the breath, but to a variable and much smaller extent, while in (4) it would not rise at all.

The reasons why steam or moist heat is superior to dry for disinfecting have been shown by Dr. Parsons to be the following:—In steam there is a greater amount of latent heat than in dry air, indeed it requires nearly 1,000 times as much heat to change 1 lb. (·453 kilogrammes) of water at 212° F. (100° C.) into steam as it does to raise the same amount of water 1° F. (·54° C.), or from 211° to 212° F. (99·46° to 100° C.). Conversely, a corresponding amount of heat is liberated when 1 lb. (·453 kilo.) of steam at 212° F. (100° C.) is condensed into water at 212° F. (100° C.). When an object is heated by being placed in hot, dry air, not only is no latent heat yielded up to it by the air, but, on the other hand, before the object can attain the temperature of 212° F. (100° C.) any water which it may contain (and all textile fabrics, even though they have been dried at ordinary temperatures, retain a quantity of hygroscopic moisture), must be evaporated. In this evaporation heat passes into the latent form, and the attainment of the required temperature is therefore delayed.

When steam penetrates into the interstices of a cold body, it undergoes condensation in imparting its latent heat to the body, also when condensed into water it occupies only a very small fraction of its former volume, for a cubic foot of steam will condense into a cubic inch of water. To fill the vacuum thus formed more steam presses forward, which in its turn yields up its heat and becomes condensed, a process which continues until the whole mass of the cold body has been penetrated. Hot air, when yielding up its heat, undergoes, it is true, some slight contraction in volume, but only to a very small extent as compared with that which is undergone by steam in condensing into water.

The specific heat of steam is greater than that of air in the proportion of about 5 to 4, that is to say, 4 volumes of steam in falling 1° F. (·54° C.), without condensing into water yield up as much heat to other objects as are yielded by 5 volumes of air at the same temperature.

Superheated steam is not so efficacious for disinfecting purposes as is *saturated* steam, because the use of steam on the point of condensing into water is a more effective way of conveying a large quantity of heat into a small space than is the use of superheated steam. The terms "superheated" and "saturated" are thus used:—At a given pressure, steam is saturated when it is of the temperature at which under that pressure it can condense, or at which water under the same pressure can become steam, whereas it is spoken of as "superheated" steam when it is of a higher temperature. At the ordinary atmospheric pressure, for instance, steam is saturated at 212° F. (100° C.).

(*C*) *To Illustrate the Liberation of Heat by Condensed Steam.*

Prepare two beakers (*a*) and (*b*) and put 56 c.c. (2 oz.) of water in each.

Fit up a flask (*c*) half full of water, and connect by means of a delivery tube (*d*) with a glass cylinder or trap (*e*) closed at both ends with rubber corks, as in *Fig.* 99.

Immerse the end of the lower tube (*f*) under the water contained in (*a*). Arrange (*c*) over a Bunsen burner, but interpose a wood or card screen to isolate (*d*) and (*f*) from the heat, insert a thermometer in (*a*) and record the temperature of the water before lighting the gas.

Boil the water in (*c*) and allow the steam so generated to pass into (*a*) through the cylinder (*e*) until the temperature of the water is raised to 60° C. (140° F.).

Remove (*c*) from the source of heat, take away the cork which carries (*d*) and pour enough of the boiling water from (*c*) into (*b*) to raise the temperature of its contents to 60° C. (140° F.). Drain the contents of both beakers into two accurately graded c.c. measures.

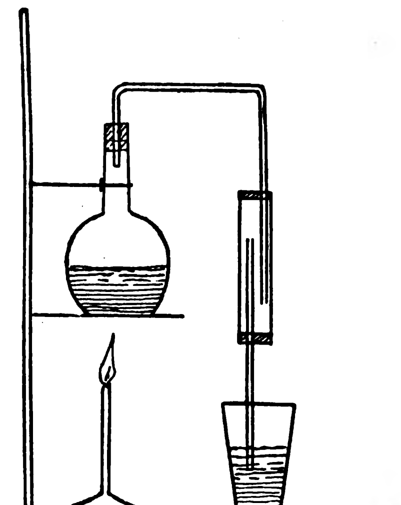


FIG. 99.

What lesson does the relative increase in the amount of water in each measure over that originally placed in the beaker teach on the subject of latent heat in steam.

NOTE.—Any given weight of steam at 100° C. (212° F.) contains sufficient heat to raise more than four times its weight of cold water to boiling point, consequently the increase in (*a*) will be very small compared with the considerable addition of boiling water necessary to raise the temperature of the contents of (*b*).

(*D*) *Disinfection by Chemicals.*

(1) (i.) Make an infusion of hay or straw as directed (*see A*), and allow it to stand for three or four days in a warm, dark place.

(ii.) Prepare four sterilized test tubes containing nutrient gelatine and label them (*a*), (*b*), (*c*), (*d*).

Immerse them in a water-bath at 60° C. (140° F.) to melt the gelatine.

(iii.) Prepare small quantities of the following disinfectants:—

(*A*)	Perchloride of Mercury ...	1 in 1,000.
(*B*)	Carbolic Acid	1 in 20.
(*C*)	Chloride of Lime ...	1 in 100.

Label each distinctly *POISON.*

(iv.) Remove the plug from (*a*) and transfer, with a sterile needle, small portions of "scum" to its surface from the hay infusion, pour a few drops of perchloride of mercury solution over these, replace the plug of wool and set aside in a warm, dark place for examination after two or three days (a temperature of 37° C. (99° F.) is advisable).

(v.) Repeat with (*b*) and (*c*), but substitute carbolic acid, (*B*), in (*b*) and chloride of lime (*C*) in (*c*) for the perchloride of mercury used in (iv.).

(vi.) Make a culture of the scum in (*d*) but use no disinfectant.

(2) (i.) Prepare four Petrie dishes (*a*), (*b*), (*c*), (*d*). Collect a little dust from the floor, walls or ledges in the room and mix it with any dirt which can be removed from beneath the finger nails.

(ii.) Pour some melted nutrient gelatine over the bottom of (*a*), sprinkle some dust over the surface and add a few drops of (*A*).

(iii.) Repeat with (*b*) using (*B*), with (*c*) using (*C*), and with (*d*) but add no disinfectant.

(iv.) Set all aside in a warm, dark place and watch for the development of any signs of yeast, moulds or bacteria.

NOTE.—The resistant spores of the hay bacillus (*B. subtilis*) are very useful for this experiment. They should be destroyed in each tube where the disinfectant solutions are used, though too much stress cannot be laid upon the important fact that solutions of sufficient strength and an exposure to their influence of sufficient length is of primary importance in effectual disinfection.

If time permit, the useful series of experiments may be advisably carried out which are suggested by Dr. Andrews in his book "*Lessons in Disinfection and Sterilization*," *J. & A. Churchill, page* 190, for some pains must be taken to correct the public misapprehension on this subject of chemical disinfection. Pupils should understand that many of the much advertized disinfectants are false to their pretensions, even when used with precautions and in quantities which are most commonly overlooked or disregarded.

(*E*) *To Illustrate the Effect of Disinfectants on Albumin.*

Prepare four beakers (*a*), (*b*), (*c*), (*d*) half-full of egg albumin solution (*page* 186). Add to

(*a*)	5 c.c. of (*A*)	Perchloride of Mercury	1 in 1,000.
(*b*)	5 c.c. of (*B*)	Carbolic Acid	1 in 20.
(*c*)	5 c.c. of (*C*)	Chloride of Lime	1 in 100.

Leave (*d*) untouched.

Compare the conditions in each beaker.

NOTE.—The turbidity and precipitation of albuminous material evident in (*a*), and to a less degree in (*b*), are the result of the formation of a relatively inert, insoluble compound which occurs when these chemicals are brought into contact with albuminous materials such as are present, for instance, in human excreta.

This property must be borne in mind when perchloride of mercury is used for disinfecting purposes in cases of typhoid fever, where the chief danger of infection lies in the discharges from the intestines and bladder, for such coagulation interferes with free access to the deeper portions of the substances with which disinfectants of this character are designed to be brought into contact.

Both (*A*) and (*B*) are virulent poisons, in addition to which, if (*B*) be used in sufficient strength to destroy resistant spores, care must be exercised to avoid injury to the skin by its caustic properties. (*A*) exercises a highly corrosive action on metals, and must be kept in stoneware or glass receptacles. (*C*) is very useful for the disinfection of excreta (fæces, sputum or urine), because by virtue of its alkalinity it disintegrates mucous and albuminous material instead of coagulating it, but it deteriorates rapidly, owing to the free liberation of hypochlorous acid, and care is necessary to ensure that reliance is only placed on freshly-prepared solutions. Limits of space forbid the introduction of more elaborate or extensive observations upon the action and characteristics of chemical disinfectants, and for the same reason no reference is made to Formalin and other valuable preparations such as Izal or Cyllin, or to gaseous or other forms of chemical disinfection. With older pupils an effort should be made to extend their knowledge upon the subject and to base this upon practical work.

(9) Finally, inasmuch as hot water, soap and a nail-brush take a foremost position in surgical cleanliness, where chemical disinfectants supplement but do not replace these means, prominence should be given to the fact that they are also at the disposal of the humblest individual. To this extent *asepsis* marks a further step in human progress than the use of *antiseptics*, upon which the public place a reliance not always justified by results.

PART V.

XXIV.—THE DWELLING. A STUDY OF SOILS.

Physical properties of soils. Water capacity and water retaining capacity of soils. Heat retaining capacity of soils. Modifying influences of salts upon the moisture in soils. Presence of carbon dioxide in soils. Absorbent properties of soils. Bacteria in soil.

SOLUTIONS USED IN DETERMINATION OF CHLORINE.

(*See IV.—" Modifying Influences of Salts upon the Moisture in Soils."*)

Standard Solution of Silver Nitrate.

Dissolve 4·797 grams. of pure silver nitrate in 1 litre of distilled water. 1 c.c. of this is the equivalent of 1 mgr. chlorine.

Solution of Potassium Chromate to be used as Indicator.

Dissolve 5 grams. (77·16 grains) of potassium chromate in 100 c.c. distilled water. Add nitrate of silver solution for the removal of any traces of chlorides present, until a red precipitate of chromate is formed. Allow it to stand, then separate the precipitate by decantation or filtration.

I.—Some Physical Properties of Soils.

Materials: *Dry earth; coarse sand; marbles; shot; alplastine; sheet of white paper; stamp paper; coarse wire or skewers; water.*

Apparatus: *Large glass vessel; gas jars; 200 c.c. measure; shallow dish; glass tubing; rubber tubing; measured ruler; balance.*

(*A*) *Granular Structure or Pore Volume.*

(1) Prepare some lumps of dry earth of various sizes. Fill a large glass vessel three-parts full with water. Drop the lumps of earth gently into the water and observe any evidence of the existence of unoccupied spaces or pores between the particles of soil. What is the nature of the substance which occupies these pores? (" Air," I. (*C*), *page* 48).

(2) Take a lump of dry earth, weigh and record the result. Measure 100 c.c. water into a shallow dish. Place the lump of earth in the dish for 15 minutes. Remove and weigh at once; compare the result with that previously obtained. Measure the water left in the dish. What quantity has been absorbed by the earth?

Does this observation confirm the conclusion formed in (1)? (*Cf.* "WATER," III. (1), *page* 68.)

NOTE.—These illustrations demonstrate, among other facts in relation to soil, that the granular interspaces are usually occupied by air and water, or by both together.

The sum total of these interstitial spaces is technically termed the "pore volume," and is expressed in percentage of the volume of the soil; it varies from 25 to 40 per cent. The wider the variation in the size of the particles the greater the divergence from the average percentage of porosity, for small particles falling into the spaces between the larger can finally reduce the interstitial spaces to a minimum. On the other hand, marked irregularity of size and shape may cause the formation of large spaces, and so increase the average pore volume. These facts are illustrated by the following experiments. (*Adapted from "Practical Hygiene." Prof. Harrington. H. Kimpton*).

(3) (i.) Take 3 gas-jars of the same capacity (*a*), (*b*) and (*c*).

Graduate three strips of stamp paper in centimetres, attach one vertically to each jar, fill the jars to the same height with water, say 50 c.c., and note the level reached on the paper scale.

(ii.) Fill a 200 c.c. measure with large shot, and add to (*a*), tapping the gas-jar gently to secure as close packing of the shot as possible.

To what level does the water now rise on the scale?

(iii.) Again fill the 200 c.c. measure, but with very small shot, add this to (*b*) treating as in (*a*). Does the water rise to a higher or remain at a lower level than in (*a*)?

(iv.) Repeat (ii.) with (*c*) but use marbles instead of shot. Take a graduated c.c. measure full of water and add enough water to (*c*) to expel all the air from the interstices between the marbles. Note this amount. The total quantity of water required in each case to reach the level of the surface of the shot or marbles represents the "pore volume" of the mass, when all particles are of the same size.

(v.) Drain the water as completely as possible out of (*c*) into a graduated c.c. measure. Record the total quantity. Then pour fine shot or coarse sand into the jar; distribute it thoroughly by shaking and tapping until all interstices appear to be quite filled and the shot or sand is level with the surface of the marbles.

Again add water from the c.c. measure until it appears at the surface of the contents of the jar. Note the amount required; is it as much as in (iv.)?

(vi.) Drain off the water again, add still finer shot or sand to the contents of the jar, then once more pour in water until it appears on the surface.

How much is required for this purpose?

To what degree has the "pore volume" been diminished by the additions of shot or sand made in (v.) and (vi.)? Give the amount of pore volume in (iv.), (v.) and (vi.).

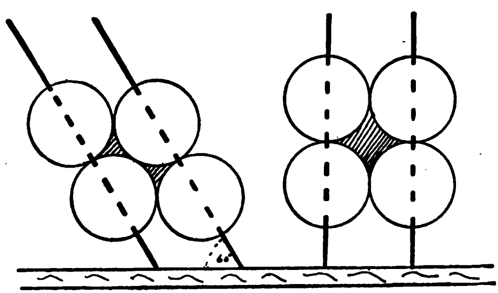
NOTE.—The water will rise to practically the same height in (*a*) and (*b*), any slight difference being the result of an inevitable want of absolute uniformity in packing and of the inequality of the spaces round the circumference of the gas-jars. It will be quite evident that the dimensions of individual grains has little influence on pore volume, if they be uniform in size, though obviously this is never the case in soils except under artificial conditions.

That the wide degree of variation in pore volume observed in Nature is due to the variation in size in particles is well demonstrated in (*c*).

In practice, the pore volume is ascertained by determining, as in (*A*), the real and apparent specific gravity of the soil, *i.e.*, the ratio of the weight of the soil to the weight of an equal quantity of water.

The pores of a specimen of dried soil (of which the specific gravity has been previously determined by weighing) are filled with boiled, distilled water; the mass is then reweighed, and the weight of the water required to fill the pores is deducted. This apparent specific gravity divided by the real specific gravity gives the proportion of the former due to the soil alone, the remainder represents the pore volume of the soil.

(4) (*a*) Make eight balls of alplastine or other modelling clay about the size of marbles. Take four short pieces of coarse wire or small skewers and transfix two balls with each piece of wire or skewer.



(A) FIG. 100. (B)

(*b*) Incline the wires or skewers at an angle of 60°, in such wise that the balls of alplastine fit one into the other as shown in *Fig.* 100 (A). Support the wires in a bed of alplastine. In soil grains thus arranged, the pore space or volume is reduced to less than 26%.

(*c*) Rearrange the wires as shown in *Fig.* 100 (B). Here the pore space will amount to 47%. The general tendency in Nature is to form pore spaces between these two extremes.

NOTE.—The finest-grained materials, including clay soils, have the largest pore space, about 47 %, whereas in coarse sand it varies from 25 % to 38 %.

The physical properties of soil are those which assume the first importance from the standpoint of hygiene. For instance, the amount of pore space determines the maximum water capacity of a soil, while the subdivision of pore space determines the rate of water percolation and drainage.

The presence of much ground water causes a cold soil and a tendency to fog, while the variations in its levels affect the degree to which organic emanations are given off from the soil, a serious matter when it is saturated with organic liquids, as in farm-yards or dirty houses. This sub-soil water may exist at any depth from two feet to three hundred, but to ensure dryness in inhabited houses it ought to be kept at a depth of from ten to fifteen feet by means of deep drainage.

Fluctuations in the level of this water are caused by rainfall, by alterations in its outfall, or by the pressure of water from the sea or rivers. Every means should be adopted to control these variations. It is even thought better to have a uniformly high level than an occasionally low one liable to wide fluctuations, which in their turn influence the proportion of ground air present in the soil.

Ground air is always unwholesome from the excess of carbon dioxide which it contains. This may amount to 3 % at a depth of 2 metres and to 8 % at three times that depth. Even 3 % is about one hundred times as much as that contained in normal atmospheric air. If 2½ % be present it is sufficient to extinguish lighted candles. In urban districts ground air also becomes seriously polluted with ammonia, nitric acid, coal gas, and the emanations from faulty sewers or cesspools.

Ground air should be rigorously excluded from dwellings by concrete foundations of sufficient area and thickness, otherwise the high temperature of the air in houses, especially when closed at night, permits this foul ground air to pass from the soil into the dwellings, to the detriment of the health of the occupants. It is also in continual movement, and especially so in dry seasons. Changes in the temperature of the soil or of the atmosphere, alterations in the level of the ground water, barometric pressure, and, of course, the rainfall are all concerned in bringing this about.

As the percentages of ground air and water depend directly upon the pore volume of soil, this particular point is intentionally dealt with in some detail, for upon the regulation of the amount of both ground air and ground

water, upon their character, upon the extent of their fluctuations, and upon their relations to inhabited houses depend to a degree as yet imperfectly realized, the health of the population and their powers of resistance to disease.

(*B*) *Permeability.*

(1) Take the specimens of large and small shot, (*a*) and (*b*), used in (*A*) (3), (ii.) and (iii.), and arrange some of them into four squares on a sheet of white paper. Make two squares of each sized shot according to the following directions; arrange a sufficient number of the large shot in a row to make a line 5 cms. (2 in.) long. Continue to arrange more shot in front of this line until a square is formed which measures 5 cms. (2 in.) on each side, placing the shot in each row one immediately in front of another in the row above, so that each shot (except the outside ones), comes in contact with only *four* others.

Make a second square of the same dimensions, with shot of similar size, but arrange the shot in the second and succeeding rows so that each touches two others in the row above. When the square is completed, each shot (except the outside ones), will then be in contact with *six* instead of four others. Then make two more squares similarly arranged, but use the smaller shot (*b*). Which form of arrangement reduces the spaces between the shot to the smaller dimensions? (*cf. Fig.* 100.)

Then consider, if these arrangements of units were carried out in a cubical form, which of them would offer the greatest facilities for the percolation of water, or be most permeable to air.

NOTE.—The distinction between the pore volume of soils and the permeability must be borne in mind. Permeability to air diminishes rapidly with the size of soil particles. It depends upon the dimensions of the individual interstitial spaces, not upon the total pore volume. Where the number of individual spaces is great so also is the number of angles, and consequently there is a rapid increase of friction, whereas the larger the size of the spaces the less the obstruction offered to the passage of air or water.

It has been shown experimentally that a fine sand, having a pore volume of 55·5%, permitted the entrance of 1 volume of air in the same time that a gravel of medium coarseness and a much lower porosity permitted the passage of 11·684 volumes.

On the other hand it will be evident that the finer the grain of the soil, or the smaller the spherical particles of which it is composed, the greater the number of passage ways there will be for the movements of air or water.

For example, if, in three specimens of soil, (*a*), (*b*), (*c*), the grains were of uniform size in each specimen, but those in (*b*) were but half the size of those in (*a*), and those in (*c*) were but one quarter the size of those in (*a*), where the coarse grains would divide a column of water into 16 streams, those in (*b*) would divide it into 64 streams and those in (*c*) would divide it into 256 streams, each having only one-sixteenth the sectional area of those formed by (*a*). The flow would, of course, be much slower in (*b*) than in (*a*), and in (*c*) than in (*b*) on account of the increased friction, though in all cases the velocity of the flow of the water is directly proportional to the effective pressure.

All soils are more or less permeable, though it is usual to classify them in two groups as permeable (chalk, sand, sandstone or gravel, etc.) and impermeable (rock, dense clays, slates, etc.). Rain rapidly reaches the ground water through the former, but is retained for longer or shorter periods by the latter.

As a rule, clays are only slightly permeable unless the grains are grouped into small composite clusters (kernels), when large interstitial spaces are formed between the clusters in dry weather.

Permeability to air is diminished by rain, and is also influenced by temperature (*e.g.*, contained moisture expands one-eleventh of its volume in freezing, when it fills this much more space).

Refer to the importance of making the walls of shallow wells impervious, otherwise foul surface water may percolate through them and possibly render the water unfit for use. When heavy rain falls and completely fills the pores of the surface soil with water, the ground air, borne down by the pressure of water above, tends to escape along the lines of least resistance.

Fig. 101 shows the risk to a shallow well of invasion (*a*) by such impure air and subsequently by the percolating water which follows it, and (*b*) of such invading water being fouled by drainage from cesspits or manure heaps. That risk is far more present in close clay than in loose soils, and is accentuated by the proximity of cesspools, manure heaps or other sources of organic impurity.

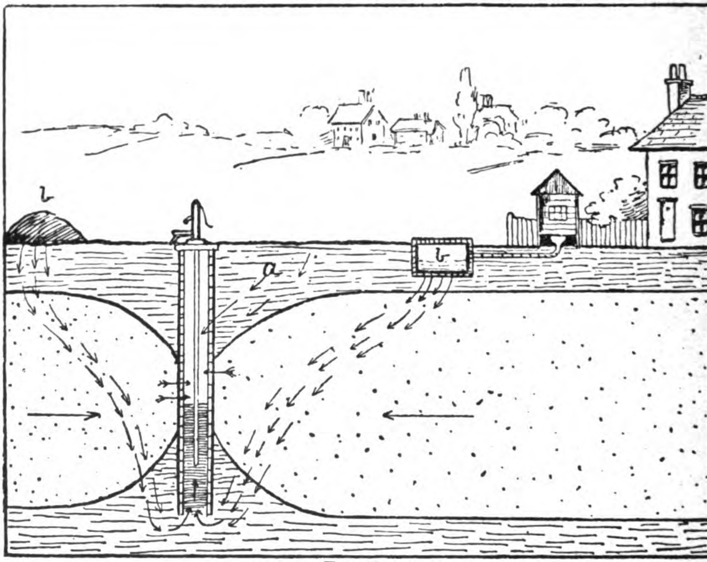


FIG. 101.

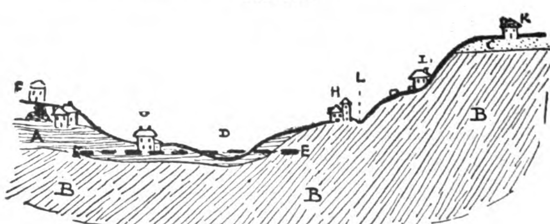


FIG. 102.

A.—Gravel or Drift.
B.—Rock.
C.—Sandy Soil.
D.—River.
E.—Ground Water.
F.—Dry and Healthy Site.

G.—Damp.
H.—Healthy.
I. —Damp and Unhealthy.
K.—Dry. Bleak.
L.—Trench for Storm Water.

A well drains an area similar to an inverted cone, of which the diameter is proportionate to the depth of the well. The more water there is withdrawn by pumping or the dryer the season, the larger the radius of the circle drained by the well.

The "subsoil" is the earth which lies directly beneath the surface soil; it may consist of gravel, sand, sandstone, loam, clay, silt (sandy mud), marl (calcareous clay), peat or chalk (*see Fig.* 102).

(2) *To Demonstrate the Passage of Wind through Soil.*

(i.) Take two large gas-jars or cylinders (*a*) and (*b*). Support in each a long glass tube which extends almost to the bottom; connect with a **U** tube by a piece of rubber tubing (*Fig.* 103).

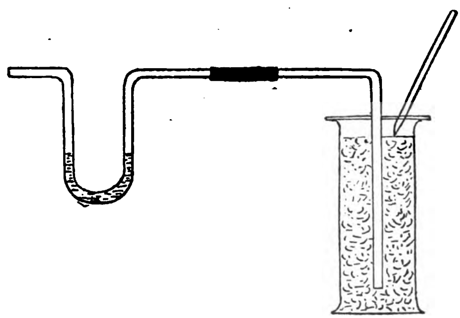


FIG. 103.

Fill (*a*) with fine sand, (*b*) with coarse gravel; then make a seal in the **U** tube with coloured water. Blow sharply on the surface of both cylinders through a glass or metal tube.

Watch the oscillation of the water in the **U** tubes; in which case is it the more marked?

(ii.) Repeat (i.) but saturate the sand and gravel with water before filling the cylinders.

Compare the results observed in (i.) and (ii.).

NOTE.—The oscillation of the water will be very slight in (i.) (*a*) or may be entirely absent, because the air which enters the surface at one point only merely communicates its motion to that immediately in its neighbourhood. No air can pass through water-logged soil, consequently there will be no oscillations in the U tubes in (ii.).

No easy and reliable demonstration can be given of the permeability of soil to air and water, for experiments require to be conducted with great care, and with air and water under known degrees of pressure.

The above demonstration merely illustrates the bald fact of the permeability of soil to wind.

The motion of the ground air is also affected by differences in temperature and by barometric pressure, but the former is by far the more important. For instance, at night when the atmosphere is colder, the air enters the soil, but as the temperature rises during the day it flows up from below, the direction of its currents being reversed.

III.—Water Capacity and Water Retaining Capacity of Soils.

MATERIALS: *Clay, coarse gravel, sand, and garden soil; coarse linen; coarse muslin or fine wire gauze; waterproof cloth or paper; cloths; mercury; ice; wire or rubber rings; lead piping.*

APPARATUS: *Bell-jar; large glass or metal cylinders; beakers; trough with set of capillary tubes; flat dishes; small bowl; thermometers; fine glass tubing; balance; air-oven; Bunsen burner.*

(*A*) (1) Procure about 1 kilo. (2 lbs.) of each of the following soils—clay, coarse gravel, and garden soil.

Label these (*a*), (*b*) and (*c*); pick or sift out any foreign matter present, such as pebbles, sticks, leaves, etc.

Weigh (*a*) with great care, arrange it on a flat dish, and dry it very thoroughly in the air-oven. If necessary, remove it at intervals during the process to crush any lumps present. When the whole is reduced to a fine powder allow it to cool and then weigh again.

The difference in weight represents the amount of moisture present.

Repeat with (*b*) and (*c*), and compare the loss of weight in the three specimen soils.

(2) Take three large glass or metal cylinders, (*a*), (*b*) and (*c*), open at each end.

Cover one end of each with fine wire gauze or a double fold of coarse muslin, well secured in position by wire or rubber rings. Further protect these covered ends of the cylinders with pieces of waterproof cloth or paper, also secured firmly in position.

(3) Weigh and record the weight of each cylinder and fill them as follows:—

(*a*) With clay, well dried, crushed to a fine powder and closely packed.

(*b*) With coarse gravel treated in the same way.

(*c*) With garden soil similarly prepared and packed.

Record the weight of each cylinder when this process is complete.

(4) Cover the open ends with coarse muslin well secured with rubber rings, then saturate the contents of each cylinder by immersion in a deep vessel of water for half-an-hour. Remove them from the vessel, take off the muslin covers and weigh again.

The result will represent the total water capacity of each soil, which depends chiefly upon its structure and composition.

(5) Stand the three cylinders in a flat dish. Remove the impervious coverings fixed in (1) and allow the contained water to drain away for at least one hour. (If the cylinders are of considerable capacity allow a longer time for drainage.) If at the end of that time this drainage process seems complete, wipe the cylinders and again weigh them.

The difference between the weight of the cylinder when containing the dry soil and the present weight indicates the water retaining capacity of each soil, and comparison with the results in (8) shows in which class of soil this water retaining capacity exists in the highest degree.

	Weight of Cylinder.	Weight filled with dry soil.	Weight when saturated.	Weight after drainage.
Clay				
Coarse Gravel...				
Garden Soil				

NOTE.—The capacity of soil to retain water is the result of capillary attraction. These forces are always active in opposition to the force of gravity. Compact soils possess the greatest retaining power, as percolation is naturally less rapid, but in all cases the amount of organic matter present materially increases the hygroscopic properties of the soil (humus, for instance, holds ten times its weight of water); from which it is evident that to keep soil clean by avoiding any deposit or discharge of filth thereon is an important factor in promoting its dryness.

Water is present in the soil under three conditions:—

(1) When it fills the pore spaces between the soil grains. This is known as *hydrostatic* or sub-soil water; it is free to move under the influence of gravity and continues its downward course until arrested by an impermeable stratum. The magnitude of the gravitational movements of water are demonstrated by the volumes of water poured into the sea by great rivers.

(2) When it surrounds the soil grains as a thin film or sheet of sufficient thickness to be slowly moved from place to place by surface tension; this is described as *capillary* water. Capillary movement occurs in all directions; it is influenced by the texture and temperature of the soil, and by the nature of the substances held in solution, *e.g.*, it is increased by nitrates and diminished by common salt and sulphate of calcium.

(3) When it is retained on the surface of soil grains, which are to all appearances dry, or air dry. This is called *hygroscopic* moisture and its movements are effected by the processes of evaporation and condensation.

The maximum water capacity of soils is stated by Professor F. H. King in his "*Text-book on the Physics of Agriculture*" to range "from about 32 to 52 per cent. or from 20 to 32 lbs. per cubic foot."

(*B*) Recall the principles of Capillarity by making the following observations :—

(1) Prepare two small beakers; fill one with water and the other with mercury.

Take a piece of fine, glass tubing and thrust it under the surface of the water; withdraw it, remove all traces of water and repeat the experiment with the mercury. Is it necessary to wipe the glass clean and dry in this case also?

NOTE.—Water rises in and adheres to the glass tube in (1) because the attracting force of the glass molecules is stronger than that of the water molecules, a force sufficient to be felt over some distance beyond the surface of the water. The row of glass molecules in that portion of the tube immediately above the the water attracts or draws up toward it a row of water molecules; as these are raised others follow them and the whole surface film of the water is raised. In the case of mercury, the relative force of molecular attraction is reversed so that the mercury is depressed around the tube and none adheres to the glass when immersed in the metal. Careful observation when conducting this experiment will show that the surface of the water becomes concave, whereas that of the mercury becomes convex when the glass tube is plunged into the beaker.

(2) Fill the trough in which a set of capillary tubes is arranged, but cool the water nearly to freezing point by the addition of ice before filling the trough. The water will be seen to rise gradually on the inside of each tube above the surface of the water in the trough, but the height to which it rises will be inversely proportional to the diameter of the tube at the surface of the water.

(3) *To Illustrate Capillary Action in Soils.*

Take four glass cylinders (*a*), (*b*), (*c*), (*d*), preferably graduated in c.c's. Cover one end of each with coarse linen or wire gauze (*Fig.* 104).

Pack (*a*) with dry powdered clay,
(*b*) with coarse dry gravel,
(*c*) with dry garden mould,
(*d*) with fine dry sand.

Support the covered ends in a shallow dish, in which water is kept at a constant level. Note by the change of colour in the soils the height to which the water rises. Mark the levels daily until the ascent ceases and compare these in each specimen.

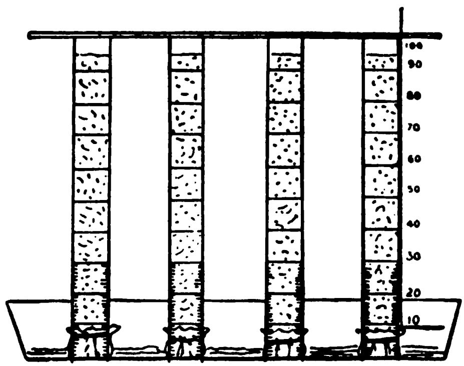


FIG. 104

In what way does the result bear upon the selection of a site for building purposes, recognizing the primary importance to health of a dry dwelling?

(4) *Observe the Hygroscopic Property of Soils.*

(*a*) Prepare well-dried samples of specimen soils and weigh out an equal quantity of each specimen. Place each for 24 hours under a bell-jar along with an open bowl of water.

Remove the specimen soil, weigh and replace.

Repeat until no further increase in weight takes place.

(*b*) Dry the soils thoroughly, then proceed to lower their temperature by placing them in deep jars and surrounding these with ice. When thoroughly chilled prepare three large bell-jars; place the same quantity of each soil used in (*a*) under each jar, under the same conditions as in (*a*), but for two hours only. Maintain as low a temperature as possible by standing the bell-jars in a cool place and covering them with cloths wrung out in water.

Remove the specimens, weigh them, and replace them under similar conditions until the weight remains constant.

(*c*) Repeat (*b*) but raise the temperature of the soil to 30° C. (86° F.) and keep them in a warm place. In which case is the greatest increase of weight recorded by the scales?

(*d*) Collect some dust from the surface of a dry road and weigh it. Spread it over a flat dish and dry it thoroughly by exposure to prolonged but not excessive heat in the air-oven. Weigh again.

The loss of hygroscopic water may amount to 10% of the weight.

NOTE.—The air confined in the bell-jar becomes quickly saturated with aqueous vapour, and this will be absorbed up to the limit of its capacity by the enclosed soil.

The amount of water absorbed by soil depends chiefly upon the relative temperature of the soil and of the air, and upon the degree of sattıration of the latter. When the soil temperature is below that of a saturated atmosphere as occurs on clear, summer nights, moistures condenses in the form of dew. In a saturated atmosphere the largest amount of water is absorbed by soils at the highest temperature. Dark alluvial loam will absorb five or six times as much moisture as calcareous silt.

III.—Heat Retaining Properties of Soil.

MATERIALS: *Clay, sand, gravel and garden mould.*

APPARATUS: 4 *deep earthenware bowls; shallow dishes; thermometer, Bunsen burners.*

(*A*) (1) Prepare four deep earthenware bowls of large diameter, (*a*), (*b*), (*c*), (*d*). Fill—

(*a*) with water; (*c*) with sand or gravel;
(*b*) with clay; (*d*) with garden mould.

(2) Register the temperature of each specimen. The bulb of the thermometer should be plunged under the surface of the contents of the bowl for 15 minutes.

Then expose the surface of the bowl to the direct rays of the sun for 2 or 3 hours. Again take and record the temperatures.

(3) Set the bowls aside in the shade, and compare the temperatures recorded after 1, 2, and 3 hours respectively.

(*B*) Take 1 kilo. (2·204 lbs.) of dry gravel, divide it into two equal portions (*a*) and (*b*).

Saturate (*a*) with water, and place both portions in large, shallow dishes arranged over Bunsen burners. Light the gas and heat both (*a*) and (*b*) for five minutes. Remove the source of heat and plunge a thermometer into each specimen; support the instruments in a convenient position for observation.

What temperature is recorded in each dish after 2 minutes, after 5 minutes, after 15 minutes, and after 30 minutes?

NOTE.—The temperature of the soil is influenced by numerous factors in addition to the length of exposure to direct sunshine or to the warmth of the air. The most powerful influence at work in depressing soil temperature is the amount of water which it contains, coupled with the fact of the high specific heat of water.

Professor R. Ulrich states that "while 100 units of heat are necessary to raise 100 pounds of water from 32—33° F., only 19·09 units are required to warm the same weight of dry sand, 22·43 units for pure clay or 44·31 units for dry humus. Thus, if a volume of water has its temperature raised 5·5° C. (10° F.) the same amount of heat would raise the temperature of an equal weight of humus 12° C. (21·6° F.), of clay 25° C. (45° F.) and of sand 31·5° C. (56·7° F.).

The chief cause of a wet clay soil being colder than dry sand or than a well-drained soil is the great amount of heat absorbed in evaporating the excess of water from the surface.

Dark soils, especially when dry, are more than ·54° C. (1° F.), warmer than light soils at a depth of 10 cms. (4 in.), while the daily variation of temperature at the same depth is more than 1·75° C. (3° F.), greater in dark than in light soil, and about ·85° C. (1·55° F.) more in soil of a medium colour.

Refer here to the association of soil temperature with the annual epidemics of infantile diarrhœa. Experience and experiment show that when the temperature of the soil reaches 13° C. (56° F.), at a depth of 1·20 m. (4 ft.), the conditions are favourable to the development of the infective micro-organism (still un-identified), which causes this disease, so peculiarly fatal to young infants.

When the soil is saturated with organic filth, as in slum neighbourhoods or in farm-yards, the colour of the soil is darkened, and all conditions of moisture, warmth, and organic matter favour the growth of bacterial life.

IV.—Modifying Influences of Salts upon the Moisture in Soils.

MATERIALS: *Sand or gravel; common salt; potassium chromate; silver nitrate solution; sheet of white paper; waterproof cloth.*

APPARATUS: *Glass cylinders; shallow glass dishes; beakers; graduated pipette; glass rod.*

Take two large glass cylinders similar to those used in II. (*A*), (1), and label them (*a*) and (*b*).

Cover one end of each with waterproof cloth. Fill each with sand or gravel of similar pore volume (I.) (*A*), but of different degrees of fineness. Make a solution of common salt, 1 in 100, and add it in equal quantities to (*a*) and (*b*).

Remove the waterproof coverings and stand the cylinders in separate shallow dishes. Add daily, for ten days, an equal volume of distilled water to each cylinder, but before doing

so always collect the drainings from each cylinder into separate vessels and test them as directed below for the presence of salt, comparing the results with the control test, which must be prepared as follows:—

Place 100 c.c. of distilled water and 5—10 drops of the indicator (solution of potassium chromate), in a beaker (*c*), and 100 c.c. of salt solution with 5—10 drops of the indicator in a beaker (*d*), standing them side by side upon a sheet of white paper.

Drop a little of the silver nitrate solution from a graduated burette cautiously into both beakers, stirring with a glass rod until the reddish brown tinge at first evanescent becomes permanent in (*d*). Note the number of drops required to gain this result. Set aside for purposes of daily colour comparison with (*a*) and (*b*). Repeat the process daily with great care for ten days, using the drainings collected from (*a*) and (*b*); note on which day in each specimen these drainings reveal the presence of salt and to what degree compared with the control test (*d*). Record the observations in tabulated form.

NOTE.—When a solution of silver nitrate is added to an alkaline solution of a chromate, a reddish-brown precipitate of silver chromate is formed. If, however, any chloride is present the silver will combine with this chloride before it combines with the chromate. When, therefore, the permanent brown precipitate is formed, all the chloride will have combined with the silver, and the amount of the silver used at this juncture will be a measure of the chlorides in the water.

The coarser sand usually yields salt on the second day and gives the highest results on the third, they then steadily diminish. The finer sand may give negative results until the fifth or sixth day.

Soluble salts in soil modify the movement of moisture in the soil and its rate of evaporation from the surface. The internal friction of soil moisture is also increased, and this affects the rapidity and ease with which pollutions travel from one level to another.

V.—The Presence of Carbon Dioxide in Soil.

MATERIALS: *Garden soil; lime water.*

APPARATUS: *Flat-bottomed flask; beaker; glass tubing; cork; balance; tripod; Bunsen burner.*

Place 28 grams (about 1 oz.) of garden soil in a flat-bottomed flask and support it over a Bunsen burner.

Fit a cork into the flask, through which passes a glass tube bent twice at right angles.

Connect the long free limb of this tube with a glass vessel containing lime water. Light the gas and note the evidence of the presence of carbon dioxide in the soil as the heat drives off the air and moisture present in the flask and its contents.

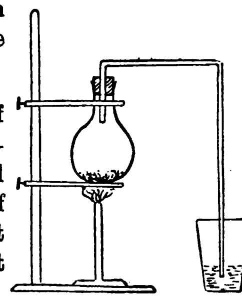


FIG. 105.

VI.—The Presence of Organic and Volatile Matters in Soil. (*Adapted from Church's "Laboratory Guide." Ed. Kinch, Gurney & Jackson.*)

MATERIALS: *Soil; peat; sodium hydroxide; carbonate of ammonium; hydrochloric acid; filter paper.*

APPARATUS: *Beakers; flask; funnel; platinum dish; tripod; Bunsen burner; balance.*

(*A*) Place 4 grams (about 62 grains) of well dried soil in a platinum dish and heat over a Bunsen burner. Regulate the flame so that the dish maintains a dull, red heat, and keep this condition until all blackening has disappeared. Allow the residue to cool, and then moisten it with a little saturated solution of carbonate of ammonium and allow to dry. Heat the specimen for about two minutes to dry off any excess of ammoniacal salt; then weigh again. Repeat with specimens of different kinds of soil. The loss represents the organic matter and combined water present in the specimen.

NOTE.—It is necessary to add the carbonate of ammonia in order to restore the carbon dioxide present in the inorganic constituents which are driven off by the heating process. The difference in weight before and after the treatment represents the organic matter, ammonium salts, nitrates, water of crystallization, etc., present in the specimen.

(*B*) Place 2 grams (about 31 grains), of peat in a flask and just cover it with a solution of sodium hydroxide. Heat for 5 minutes over a Bunsen burner, remove the source of heat, add a little distilled water to the contents of the flask, and filter. (Be careful to wet the filter paper before doing so.)

Add an excess of dilute hydrochloric acid to the filtrate. If this be dark-brown and the addition of the acid cause a flocculent precipitate, the presence of organic matter is indicated.

NOTE.—These organic acids, derived from the decay of organic matter, form soluble salts from alkalies, but are nearly insoluble in water.

VII.—The Absorbent Properties of Soil.

MATERIALS: *Loamy soil or peat; solution of litmus, cochineal, or logwood; ammonium hydrate; turmeric paper; filter paper.*

APPARATUS: *Wide-mouthed bottle or jar; beakers; funnel; balance.*

(*A*) Put at least 100 grams. (3·52 oz.) of loamy soil or peat into a wide-mouthed bottle or jar, and soak it with a weak solution of litmus, cochineal, or logwood. Shake the mixture well; then pour the liquid into a wetted filter and collect the drainings into a beaker.

What evidence does the filtrate give of the coloured solution with which the soil was saturated?

(*B*) Make a similar mixture of soil and liquid, but substitute a solution made in the proportion of 5 drops of ammonium hydrate to every 100 c.c. of water. Test this solution with turmeric paper before use. Note the reaction given.

Filter the fluid from the mixture. Test the filtrate with turmeric. Is the reaction affected? Does the filtrate smell of ammonia?

NOTE.—The great affinity of soils for colours and odours is a source of risk to the ignorant, for liquid sewage and the drainage from manure heaps lose both colour and smell when they have passed through a substantial layer of earth, though their deleterious characteristics are little affected.

No offensive odours penetrate a layer of earth, if of sufficient depth, a property of great value when directly employed in connection, *e.g.*, with earth closets, but of equal danger when its exercise has divested coal gas for instance, of its characteristic odour, so that it can be drawn into houses unnoticed with the ground air, until its poisonous effects lead to a realization of its presence.

VIII.—The Presence of Bacteria in Soils.

MATERIALS: *Specimen soils as in II.; house refuse; nutrient gelatine.*

APPARATUS: *Petrie dishes; large pot of fresh garden soil.*

(*A*) Prepare three Petrie dishes (*a*), (*b*), (*c*), and have also ready prepared small quantities of the specimen soils used in II. (*A*).

Melt some nutrient gelatine, pour a thin layer over (*a*), sprinkle a few grains of clay over the surface just before the gelatine solidifies, and set aside in a warm, dark place.

(*B*) Repeat with (*b*) using gravel, and with (*c*) using garden soil, and set aside with (*a*). Examine each specimen daily after three days for indication of bacterial growth.

In which of the three is this the most active?

(*C*) Prepare a large pot 30 cms. × 25 cms. (12 × 10 ins.), and fill it with garden mould.

Bury a small quantity of house refuse, vegetable and animal, at a depth of 10 to 12 cms. (4 to 5 in.) below the surface of the soil. Stand the pot out of doors where it will be secure from the depredations of cats, but exposed to the sun and rain.

Examine the soil after three months for any evidence of the organic matter buried beneath its surface.

NOTE.—If the directions are carefully followed the whole should be converted into mould, except any mineral matters such as bone. The quantity of organic material must be small, and the soil in the pot should be dug fresh from the garden.

IX.—The Importance of Bacteria in Soil.

MATERIALS: *Garden soil; milk; starch jelly; sugar; soap; broad beans; peas.*

APPARATUS: 4 *small pots; c.c. measure; balance; air-oven; Bunsen burner.*

Sterilize 500 grams (1·1 lbs.) of garden soil by exposing it for some hours on three consecutive days to a temperature of 105° C. (221° F.) in the air-oven. In the same way sterilize 200 c.c. of milk, 200 c.c. of starch jelly (*page* 186), and 200 grams of sugar, mix all three ingredients thoroughly with the sterilized soil.

Cleanse four small pots (*a*), (*b*), (*c*), (*d*), with hot water and soap, and dry; then fill (*a*) and (*b*) with the above mixture, moisten with warm water, and plant (*a*) with broad beans, (*b*) with peas, previously soaked in water for 48 hours. Fill (*c*) and (*d*) with similar, but unsterilized, soil, sow (*c*) with broad beans and (*d*) with peas.

Keep all four pots under good conditions of moisture and warmth. Observe the subsequent development of the seeds.

After three or four weeks, add a little unsterilized earth to (*a*) and (*b*), keeping careful watch for any changes which occur throughout the experiment.

NOTE.—The bacteria in soil are present almost entirely in its superficial layers, the richer the amount of organic matter the greater their number and activity. From hundreds of thousands to millions may exist in 1 c.c. of well manured garden soil, but their numbers are much less in clay or sand, while at a depth of from three to four metres the soil is practically sterile.

Soil bacteria are mainly saprophytes (*page* 452) and beneficent in their work, though certain exceptions are found, for instance, in the bacilli of tetanus (lockjaw) and of

malignant œdema which are present in cultivated ground. For this reason even insignificant skin abrasions caused by falls in gardens or on paths or roads should be carefully and promptly cleansed. Peat exercises a specially destructive influence upon these pathogenic bacteria, though they can rarely thrive in any kind of soil in consequence of the enormous number of saprophytes.

There is, however, experimental evidence that infectious organisms may retain their vitality for long periods at considerable depths in the soil and resume all their malign characteristics when brought to the surface and restored to favourable conditions of heat and moisture.

A mistake is made in burying organic matter at a great depth in the soil if its destruction is desired. Dr. Vivian Poore proved the efficacy of disposing of it in 16 cms. (6 in.) trenches and merely sprinkling it with sufficient earth to disguise what is beneath (*See* "*Rural Hygiene*," *Chapter IV.*, "*The Living Earth*"), for the action of bacteria is essential to the processes of organic change which take place in soil, and those kinds of bacteria which carry on the processes of decomposition can only do so in the presence of oxygen, with which they are supplied to a depth of 30 cms. (1 foot).

The weak condition of the seedlings (*a*) and (*b*), grown as prescribed in (IX.), also illustrates this point, for they do not thrive until soil laden with bacteria is added to the sterilized soil in which they are sown. The mere presence of organic matters is insufficient for plant nutrition, it is only after their bacteriological decomposition that they can be absorbed by vegetable life. The sterilized soil was richly furnished with the proximate principles of food, but in forms unassimilable by plants until broken down into simpler constituents by the aid of micro-organisms.

The most important source of nitrogen in the soil is the outcome of the slow decay of organic matter, vegetable and animal, but the process known as *symbiosis* (*i.e.*, living together), ranks next in order of importance as a means for maintaining the constant, necessary supply of nitrogen.

Hellriegel published the results of his studies on this subject about twenty years ago, in which he established the fact that the roots of leguminous plants are inhabited by vast numbers of micro-organisms which withdraw free nitrogen from the soil air for their needs; the two forms of

life live together, and so are said to be in symbiotic relation. This must be clearly distinguished from parasitism, *i.e.*, living upon, or drawing sustenance from another.

There are also other important kinds of soil bacteria known as nitrifying bacteria. These form the last link in the chain which unites the animal with the vegetable kingdoms, for they reduce (or cause an oxidation of) the complex nitrogenous products of the animal world, by means of which the ammonia is joined with oxygen, and the result, in the form of nitrates, is left in the soil to be absorbed by the roots of plants which are incapable of deriving nutriment from less simple chemical combinations.

XXV.—BUILDING MATERIALS.

Tests for the quality and characteristics of bricks, building stones, slates, stoneware, mortar, and wood. Damp-proof courses. Inspection of a house in course of construction.

I.—Tests for the Quality and Characteristics of Bricks, etc.

MATERIALS: *Bricks, pressed (Chester), red facing (Ruabon), Brook Hill blue, red (Sevenoaks), salt glazed (Leeds), coarse stock brick; building stones, Portland, Bath, Kentish rag, sandstone; slates; models, brick, sink, drain pipe or trap in glazed stone-ware or fire-clay; specimens of white and yellow deal, pitch pine, oak, teak, and jarrah; quicklime; sharp river-sand or grit; sea sand; street sweepings; lumps of sugar; specimen Callender's Lake Bitumen damp course, fibrous asphalte or tile of vitrified stoneware ventilating damp course;* 4 *sheets of thin lead,* 22 *cms.* × 5 *cms.; waterproof paper; small blocks of wood; wire; cloth; cotton wadding; labels; sulphurous acid; writing ink; methylated spirit; taper; water.*

APPARATUS: *Hammer; trowel; chisel; metal tray; large glass jar; bell-jar; pneumatic trough; c.c. measure; earthenware dish or bowl; plate; shallow dishes; balance.*

(*A*) *Bricks.*

Take the specimen bricks provided and test their qualities in respect of :—

(1) Toughness; do they snap at once when forcibly struck with a hammer or trowel, or are several hard blows required to break them.

(2) Sound; is this a dull heavy thud or a clear ringing note when one brick is used to strike another gently?

(3) Non-porosity; to make this test, proceed as follows :—

(i.) Select five bricks of the different kinds named below, all should be, if possible, of the same dimensions, about 23 cms. × 11 cms. × 6 cms. (8·9 × 4·2 × 2·5 in.). Label them

- (*a*) Pressed (Chester)
- (*b*) Red-facing (Ruabon)
- (*c*) Brook Hill blue (Chester)
- (*d*) Red (Sevenoaks)
- (*e*) Salt-glazed (Leeds)
- (*f*) Ordinary stock brick.

Weigh each specimen with great accuracy.

(ii.) Prepare a pneumatic trough or other deep vessel three-parts full of cold water. Stand the bricks on end in the trough for the periods of time directed below, weighing each and recording their weights after each immersion.

Description of Brick.	Dry Weight.	Increase of Weight after				
		1 sec.	1 min.	30 mins.	1 day.	1 week.
Pressed Brick						
Red Facing						
Brook Hill Blue ...						
Red						
Salt Glazed						
Stock Brick						

NOTE.—So far no scientific test has been formulated for the quality of bricks; architects and engineers still estimate this by rule of thumb methods.

The observations made in (*A*) are based upon the standard adopted by a prominent architect. No test for the durability of bricks, that is for their powers of resistance to wind and weather or to the acids present in the air and rainfall of our large cities, has yet been adopted.

It is most important to test the *amount* of water which a brick will absorb, because it affords some indication of the liability of walls to become more or less saturated with damp, as well as the degree to which such bricks will be acted upon by rain or frost. The *rate* of such absorption is of even greater importance; if it be rapid every shower may cause dampness, if it be slow it is evident that only long continued rain will seriously affect the walls in this respect.

As a rule the heavier the brick the less the amount of water absorbed in the given time, but the rate of absorption depends largely on the nature of the outer skin of the brick. If this be smooth, vitrified, and free from cracks the rate of absorption will be slow, for the contained air finds as much difficulty in making its escape as the water does to gain an entrance, whereas carefully conducted experiments have shown that coarse, soft, under-burnt or fissured bricks will absorb 85% of the total amount of water they can hold in half an hour. "Pressed" bricks are usually the best, they are dense, impervious and smooth. Ruabon red bricks and the Staffordshire blue bricks are also among the best in the country.

The introduction of enamelled bricks or salt glazed bricks is a step in sanitary progress. They are hard, durable, non-absorbent and easily cleansed, as well as possessing the æsthetic advantage of rich and varied colours. The quality of bricks is an economic as well as a hygienic question. Damp walls require in a house much more firing than do dry ones, on account of the cold caused by the constant evaporation of moisture. There is also good reason to believe that such diseases as phthisis and cancer are more prevalent in damp than in dry dwellings.

(*B*) *Building Stones.*

Examine the four specimens of building stones provided, weigh them carefully and subject them to a test similar to that directed for bricks in (*A*) (3) (ii.).

Description of Stone.	Dry Weight.	Increase of Weight after				
		1 sec.	1 min.	30 mins.	1 day.	1 week.
(*a*) Purbeck Portland...						
(*b*) Bath						
(*c*) Kentish Rag ...						
(*d*) Sandstone						

NOTE.—If possible the specimens of these different stones should be of the same shape and weight, otherwise somewhat elaborate calculations will become necessary if comparisons are to be instituted, for these become almost impossible when the surface area of the specimens varies widely, even if weights correspond.

Besides rendering a house damp and cold, an absorbent building stone is more likely to decay prematurely.

The Board of Education Building Regulations require stone walls to be 50 cms. (20 inches) thick, while solid brick walls need only have a depth of 33 cms. (13½ inches), because, owing to the irregular shape of stones, a "bond" cannot be obtained in a thin wall.

(*C*) *Slates.*

Take the specimens provided and make observations on the points enumerated by the use of the following tests :—

(1) *The Surface.*

Can this be scratched with the finger nail, does it feel smooth and greasy to the touch, are the edges friable or firm and even ? Are the grains of which it is composed compact and fine, do they run in the direction of its length, is the colour uniformly dark or light ?

(2) *The Sound.*

Strike the slates sharply with the knuckles. Is there a metallic ring or a dull thud ?

(3) *The Odour.*

Breathe upon the slates and then smell them. Is there an earthy or clayey smell emitted or are they inodorous ?

(4) *Toughness.*

Strike the slate with a hammer or knock it sharply against a hard substance. Does it break with a clean fracture?

(5) *Porosity.*

(*a*) Weigh each specimen of slate and completely immerse it for 24 hours in cold water. Weigh again. What increase is evident, is the relative amount equal in each case?

(*b*) Thoroughly dry the slates, then arrange them on edge in the pneumatic trough and pour in water to cover half their depth. Leave in position for 12 to 18 hours. Remove the slates from the trough and measure the height to which the water has risen in each of the specimens above the level of that in the trough. What is the character of the line formed, waved or straight?

(6) *Resistance to Atmospheric Influence.*

Procure a large glass jar and carefully pour in 50 c.c. of a saturated aqueous solution of sulphurous acid. Perforate holes in small slips of the different specimens of slate under examination, and suspend these slips in the jar by means of wire passed through the holes and fastened to the neck of the jar. Cover the mouth of the jar for 24 hours with a glass plate or bell-jar. Then remove the slates and examine them for any change during this period.

Compare your observations with the following characteristics of a good slate accepted by the Institute of Sanitary Engineers:—

(i.) Slate must be hard in substance and rough in surface grain or otherwise it will absorb water, if greasy to the touch it is of inferior quality. It must be non-friable at the edges, fine in grain, even, and not too dark a colour. The black varieties are both more absorbent and more liable to decay.

(ii.) The ring must be sharp and metallic.

(iii.) A good weathering slates gives no odour.

(iv.) A good slate breaks with a clean fracture.

(v.) It must not absorb more than $\frac{1}{200}$ of its weight of water, nor should water rise by capillary action (*see* "Soils," *page* 577) more than 3·1 mm. ($\frac{1}{8}$ inch.) above the level of that in the vessel; the water-line must be straight, not waved.

(vi.) A good slate shows no sign of "scaling" after exposure for 24 hours to the vapour of sulphurous acid. The best qualities will stand this test for weeks.

Note.—Slates are known as clay or stone slates. The latter are heavy, somewhat absorbent, but durable, and warmer than the former; they are usually employed only for repairs, or additions to the roofs of existing houses. There are many qualities of clay slates, which come chiefly from N. Wales and the English Lake district.

Specimens of at least three varieties should be procured for this experiment.

(*D*) *Glazed Stoneware or Fireclay.*

(1) Select two or three specimens of different objects which are employed in house construction, and which are made from these materials, such as a model brick, a sink, a stoneware and a fireclay drain pipe, or a trap.

Wash each specimen, dry thoroughly and weigh, then immerse in water for some hours. Remove from the water, dry with a cloth, and weigh again.

Articles of a good quality should show no change in weight, as the glaze used in their manufacture renders them entirely non-absorbent.

(2) *Test for Quality.*

(*a*) Cut away the glaze at several points on each of the specimens used in (1). Drop ordinary writing ink on to the stoneware and fireclay. Does the ink spread under the glaze or remain circumscribed in the spot where it was dropped?

Articles are of inferior quality when the ink diffuses under the glaze.

(*b*) Tap the specimens sharply with a chisel or other sharp metal instrument. If the glaze cracks and flies in brittle pieces like an egg-shell the quality is not good.

NOTE.—True stoneware is more porcelainous than fire-clay, being made from clays formed of disintegrated granite; it does not depend upon its glaze for its non-absorbent properties, for, even when badly glazed, stoneware is less absorbent than fire-clay, which must be always well glazed when employed for sanitary purposes.

(*E*) *Observations on Mortar.*

(1) Weigh an earthenware dish or bowl; then place in it a lump of quicklime about the size of a small hen's egg.

(2) Pour cold water carefully over the lime until it is saturated, that is, until it can absorb no more water. It will become hot and crumble away during the process.

(3) Weigh the dish and its contents, the increase will represent the weight of slaked lime. Add twice this weight of fine, clean, sharp river sand or grit, mix thoroughly with an iron trowel or spoon, turn the mass out on to a wooden board and leave for a week.

(4) Repeat the above twice, using respectively sea sand and street sweepings rubbed through a fine sieve, in place of the clean, sharp sand.

Compare the product in each case after it has been exposed to the air for 1 week, 6 weeks, three months, and six months.

NOTE.—It is difficult to over-estimate the importance of good mortar in the construction of good, sanitary houses. If made of poor or unhealthy materials or if these are used in wrong proportions, mortar allows rain and wind to penetrate the walls, favours the growth of vegetation, cracks easily and crumbles easily; the whole leads to general decay of the walls, for the "arrises" of the bricks and stones becomes exposed to the action of the atmosphere. The temptation

to scamp mortar is very strong—gas-lime is substituted for freshly slaked lime and filthy road scrapings may take the place of clean, sharp sand.

The sand used should be angular in grain, not round, nor mixed with clay, iron, ashes, soot or organic matter (such as dung in road sweepings), which favour the colonization of the house walls with myriads of micro-organisms. Mortar made with sea sand causes dampness on account of the hygroscopic properties of the salt. Burnt "ballast" or broken brick are admirable if properly ground, sifted and mixed.

The addition of Portland cement of a good quality and in right proportions (Portland cement 1 part, gray lime ½ part, clean sharp sand 2—3 parts), is highly advantageous as regards strength and durability. It must be remembered that in any volume of sand the interstices between the grains constitute from one-third to one-half of the bulk; if, therefore, it be present in undue proportion the mortar will be distinctly pervious and of inferior quality. Professor Tichborne found the relative porosity of certain mortars and asphaltes to be as follows:—

Common lime-mortar (1 lime, 2 sand)	100
Plaster of Paris	75
Roman cement	25
Portland cement	10
Asphalt	0

The chemical explanation for the "setting" of mortar is found in the fact that the slaked lime absorbs carbon dioxide from the atmosphere, the water with which the lime was slaked is evaporated, and carbonate of lime is formed.

This test may, if time permits, be well repeated with cement, for which it is in habitual use, when the cement is to be employed in sanitary work.

(*F*) *Woods.*

Examine the specimens of wood provided for the purpose; deal (white and yellow), pitch-pine, oak, teak, and jarrah.

Test as follows their relative capacity for

(1) the absorption of water;
(2) resistance to fire.

(1) Prepare a pneumatic trough or shallow dish with a layer of water about 5 cms. (2 in.) deep at the bottom. Weigh and label each sample of wood and support them on end in this vessel, leave them in position for 24 hours. Remove the woods and weigh again; in which is the power of absorbing water most pronounced.

(2) Prepare a metal tray and cover its surface with a layer of cotton wadding, slightly sprinkled with methylated spirit.

Lay the specimens of wood, previously dried, upon the wadding and ignite it with a taper at least 45 cms. (18 in.) long. Be most careful to isolate the tray from the surrounding objects; close the door of the room in which the test is made in order to avoid draughts, and remain at least 45 cms. (18 ins.) away from the tray while the combustion is proceeding.

When the specimens have cooled, arrange them in order of inflammability as indicated by their charred remains.

NOTE.—Pines are the most combustible of woods, oak and teak the least so. Oak may be only charred by a fire which causes granite and limestone to crumble to powder. Solid wood floors possess fire-resisting properties of great value on account of the absence of crevices or air-spaces which cause draughts and increase the combustion.

The great danger to be feared in ground floors made of wood is the kind of decay known as dry rot. This is a fungus, *Merulius lacrymans*, of which the development is fostered by the conditions favourable to the growth of any low form of life, *viz.*, dampness, warmth, stagnant air and absence of light, especially of sunlight. (*See* "*Methods of Food Preservation,*" (*A*), (*B*), *page* 454.

The annoyance can be obviated by the use of impervious ground layers and damp-proof courses, and by adequate ventilation under the floors; that is, ventilation must be ensured on two sides, opposite, not at right angles to each other. Care must be taken that the air grates below the floor level do not become blocked, and the consignment of wood for flooring purposes should be examined for traces of white fungoid growth before use.

Other sources of this trouble are found in impervious floor covering, such as linoleum or parquetry which prevent the passage of air, or in chips of damp or dirty wood left under floors when they are closed down. A musty, mushroomy smell is sometimes the first warning given; on removal of the carpet, fine filaments of the plant will probably be seen round the skirting and a crop of large fungi will be revealed when the floor is taken up. Nothing will eradicate the evil but taking up the whole floor and saturating the bases of the walls and the floor area with a hot solution of lime; after which the whole surface must be covered with cement concrete before the boards are relaid.

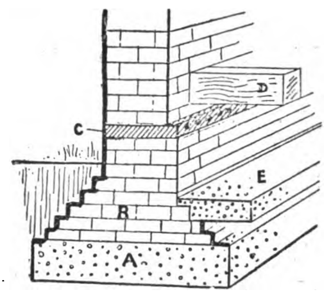


FIG. 106.

BRICK AND CONCRETE FOUNDATION, 18 INCH WALL.

A.—Concrete Foundation 4 ft. wide.
B.—Brick Footings.
C.—Stoneware ventilating damp-course 3 in. thick.
D.—Wood floor joist.
E.—Concrete ground layer.

(*G*) *Damp-proof Courses.*

(1) (*a*) Take 6 lumps of sugar and pile one on the top of other on a plate.

(*b*) Arrange a second column of six, but insert a small square piece of waterproof paper between the second and third lumps. Place a little coloured water on the plate of a depth to touch the bottom lump of each column. Leave for ten minutes.

What difference is now evident between the two columns of sugar? What property of water does this illustrate?

(2) Prepare a shallow dish or tray to measure at least 60 cms. (2 feet) and pour in water to the depth of 5 cms. (2 inches). This level should be kept constant throughout the experiment. Take six bricks of as nearly as possible the same size and character, build these into two piles of three bricks each, (*a*) and (*b*), the bottom brick of each pile to rest horizontally in the trough.

Insert a piece of Callender's Lake Bitumen Damp Course, a piece of fibrous asphalt, or a specimen tile of Vitrified Stoneware Ventilating Damp Course between the two lower bricks in (*b*). Leave the whole in position for some weeks, or even months. Note the gradual evidence of dampness in the upper bricks of (*a*), which will lead to the growth of different forms of moulds and to an increase of weight if this be tested at intervals.

(3) *To illustrate risks from capillary action in carelessly constructed sheet lead "drips."* (*Adapted from "Elementary Science Applied to Sanitation and Plumbers' Work." A. Herring Shaw*).

Procure four sheets of thin lead to measure about 22·5 × 5 cms. (9 × 2 inches).

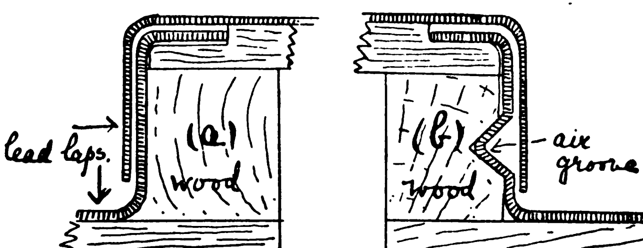


Fig. 107.

Take two small blocks of wood 15 × 5 cms. (6 × 2 inches) and arrange the lead upon the wood as shown in *Fig.* 107 in a shallow dish containing water; label the blocks (*a*) and (*b*) respectively.

Leave both arrangements in position for some days in a *cool* place.

Refer to "A STUDY OF SOILS," (*B*), *page* 577, for an explanation of the results in (1) (*b*), (2) (*a*) and (3) (*a*).

NOTE.—To secure a dry house is a difficult but important matter; moisture must be excluded from both the ground and the atmosphere, while fresh air must be admitted freely. Damp may gain access to a house through the foundations, floors, walls, roof or windows, it may be caused by a damp site, by defective water-pipes or by the back-flow of drains.

To exclude ground moisture, in addition to drainage of the sub-soil, the whole excavated site under the lowest floor of the house must be covered with an impervious layer of concrete (*see Fig.* 106), while every wall should have a horizontal damp-proof course above the external ground and below the ground floor. If the basement be inhabited, there must be a second horizontal damp-proof course outside the wall, or an open area may be constructed to a depth of 15 cms. (6 in.), below the basement floor.

In addition to the employment of suitable materials for the walls there should be asphalt damp-proof courses under all parapets and gutters; eaves, gables, and window-sills must project in such a fashion as to throw moisture clear of the walls; slates and tiles should be laid on waterproof felt, and sufficient lead must be used for the "drips" to ensure their efficacy, otherwise capillary action is set up by the close contact of sheets of lead which completely defeats the object with which they are applied. (*See Fig.* 107).

Good asphalt constitutes a first-rate damp-proof course; sheet lead is excellent also, but expensive; Portland cement, mortar, and slates embedded in cement or mortar, are none of them reliable, the two former are not entirely impervious, and the two latter are liable to fracture.

II.—Inspection of a House in Course of Construction.

(*A*) *Introductory.*

Plans, Sections, and Elevations are the names given to the mechanical drawings of architects, by means of which the form, size, and arrangement of a building are indicated to clients, builders and others. A definite scale is adopted to represent the particulars, few, if any, of which could be drawn to full size. This scale varies according to the work, thus a whole building may be represented to a scale of $\frac{1}{8}$ or

¼ in. to the foot, *i.e.*, 8 or 4 feet to the inch, while details of its parts may be shown at a scale of one or more inches to the foot.

Plans should also show the fittings designed for the water service, cistern, waste pipes, soil pipes, drains, gas pipes and ventilators, &c., the position of which is of the first importance.

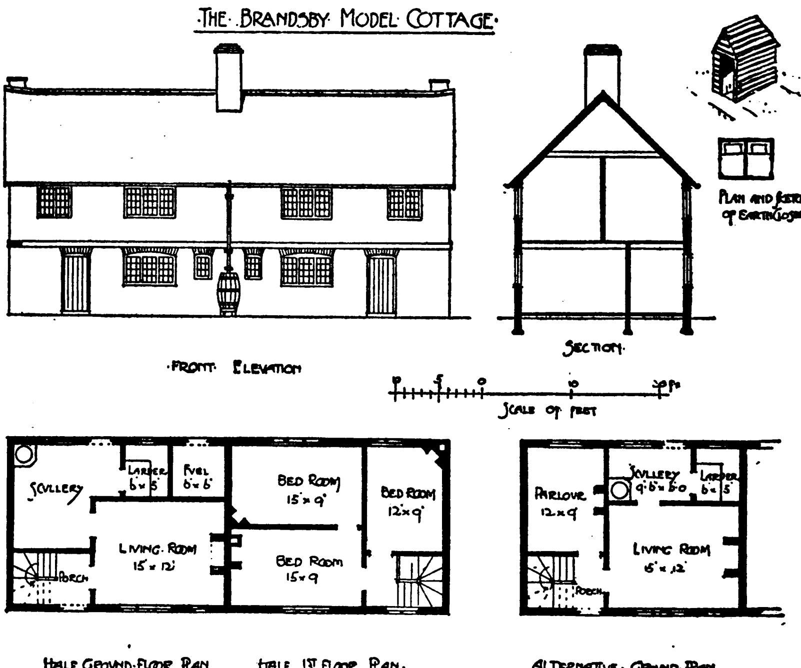


FIG. 108.

(a) *The Front Elevation* shows the height of, and width of, the building, with the position and sizes of the doorway and front windows.

(b) *The End or Side Elevation* shows the distance from front to back, the dimensions of the end and the slope of the roof.

(c) *Horizontal Sections*, usually called *Plans*, shows the thickness of the walls, the area and shape of the rooms, the positions of doors, windows, fireplaces, staircase, etc.

(d) *Vertical Sections*, of which, as a rule, but one is prepared, show the height of the rooms, the depth of the floors and of the foundations, with other details of construction.

It is a great art to utilize to the full the entire space at the architect's disposal and to afford the tenant all the accommodation, convenience, and comfort attainable. No "cul de sac" for stagnant air, no dark or unventilated corners should be allowed. It is hoped that in future far more attention will be devoted to what are now called trifling details.

As the dimensions of all the various parts cannot be shown in one drawing, it is usual to prepare at least four different views, three of which are illustrated in *Fig.* 107, which show the plans of a model cottage erected at Brandsby, Yorkshire (reproduced by kind permission of the Rural Housing and Sanitation Association).

(*B*) The plans of the house to be inspected should be procured and explained before the visit is paid. Elder pupils should be trained to read such plans intelligently, and to understand the conventional signs employed to indicate dimensions, the lengths to which these refer, the positions of doors, windows, fireplaces, stairs, sanitary conveniences, etc.

When the inspection is made, direct attention to the following points and observe so far as possible the extent to which these agree with the requirements of the local Building Bye-laws, of which a copy should be procured for the purpose.

(1) *Foundations.*

(*a*) Nature of soil and method of sub-soil drainage.

(*b*) Position, area and depth, at least 15 cms. (6 ins.) of concrete foundations.

(*c*) Footings, *i.e.*, the spreading of the walls at their base by means of off-sets, which should extend to depths varying with the nature of the soil, from 15 cms. (6 in.) on hard sand, chalk or rock, to from 1 to 6 metres (3 to 20 ft.) on clay, according to the weight of the building. The bottom layer should be twice the width of the wall thickness at the ground level (*see Fig.* 106).

(2) *Walls, Outside.*

(*a*) Their thickness and materials; hollow or solid.

(*b*) The position and material of the damp-proof courses.

(*c*) The shape of the mortar joints (*Fig.* 107).

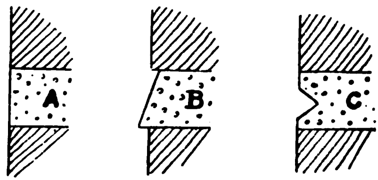


FIG. 109.

MORTAR JOINTS.

A.—Flat or flush—bad.
B.—Mason or weathered point—good.
C.—Common form of finish to A.

(*d*) The bond of brickwork employed. English or Flemish.

(*e*) The copings, whether of bricks, stone, terra-cotta, or concrete blocks.

(*f*) The provision for ventilating under the floors by means of air bricks (*see Fig.* 106).

Inside.

(*a*) The material used for partitions, brick or lath and plaster.

(*b*) The measures taken to make lath and plaster partitions sound-proof. (Slag felt wool is useful for the purpose, it is fire, damp, sound and vermin proof. The material is produced by blowing off waste steam into the slag of iron furnaces.)

(3) *The Roof.*

(*a*) The slope (flat or pitched) and materials, slates, tiles, lead, etc.

(*b*) The presence of a non-conducting or impervious layer between the outer covering of the rafters and the slates, tiles, etc.

(c) Damp-proof courses at the junction of the parapet and lead gutter and between the roof and chimney-stacks.

(d) The position of eaves, gutters and rain-water pipes. The latter should be fixed 5 to 8 cms. (2 or 3 inches) away from the walls.

(4) *The Rooms.*

Note:—

(a) The aspect and size of the rooms;

(b) The positions of doors, windows and fireplaces;

(c) Any special convenience designed to promote the purpose for which the rooms are planned; for instance, the proximity of parlour and kitchen, ample ventilation in the scullery, light and cool aspect for the larder, a hood to the wash-house copper, and an inconspicuous but airy position for the sanitary conveniences, fireplaces and cupboards in the bedrooms and bathroom, and provision for air and light on the staircase.

(5) *The Floors.*

(a) Whether of flags, tiles, concrete or wood.

(b) If of wood, are they single, double or framed, or composed of blocks laid in a mixture of tar, asphalt or concrete?

(c) Are the joints of the floor-boards square-edged, splayed, or tongued and grooved?

(d) What steps have been taken to deaden the transmission of sound? Has the space between the joists been left open or filled with undesirable saw-dust or lime-plugging. (Hard silicate-cotton slabs or slag-wool are recommended for this purpose.)

(6) *Windows.*

(a) Size, position and number, with reference to the admission of air and light.

(b) Are they sash or casement?

(*c*) Calculate the proportion they bear to the floor area in each room. This proportion should be at least one-sixth, of which one-half should be made to open at the top.

(7) *The Pipes and Cistern.*

(*a*) The source of the water supply and method of drainage.

(*b*) The arrangements for the supply of water, gas or electric light, and for the removal of waste matter, liquid and solid.

(*c*) Are the pipes protected from damage or from extremes of temperature, are they accessible for repairs ?

(*d*) Is the sanitary convenience well placed and efficiently ventilated, well away from the bed-rooms and larder.

NOTE.—These observations can be extended or curtailed according to the age of the pupils. The reasons for each point enumerated should be discussed and explained.

The additional cost should be discovered, and its hygienic aspects considered, which is incurred by the provision of good foundations and damp-proof courses, by the use of impervious, non-conducting layers in roofs, of sound-proof partitions in the walls and of similar layers in floors. Impress the close connection between economics and health in all these details of house construction, upon which the well-being of the occupants directly depends.

XXVI.—VENTILATION.

Principles of practical ventilation. Inlets and outlets. Formula for calculation of air supply. Cubic space and air supply. Shape and position of inlets. Gaseous diffusion. Sources of impurity. How to estimate the condition of the Atmosphere. Inspection of an installation for purposes of mechanical ventilation.

TO MAKE THE SOLUTION OF PHENOL-PHTHALEIN.

Dissolve 1 gram of phenol-phthalein in 100 c.c. of distilled water with the aid of about 10 c.c. of alcohol.

I.—Principles of Practical Ventilation.

MATERIALS : *Alplastine; sheet of cardboard; wooden wedges; tapers; light feather; clean cloth; rubber corks; water.*

APPARATUS : *Large chimney; large bell jar; shallow dish; glass tubing; forceps; sharp knife; measured ruler.*

(*A*) Support a taper in a shallow dish by means of a small pad of alplastine, light it, and enclose it within an ordinary lamp chimney; then pour water into the dish to a depth of about 2 cms. ($\frac{3}{4}$ in.). This will prevent access of air to the taper from below, by sealing the junction between the dish and the bottom of the chimney.

Watch the flame of the taper, and just before it is extinguished insert in the top of the chimney a piece of card previously cut to the shape of the letter **T**. The cross-piece will support the card by resting on the edge of the chimney, the long limb of the **T** should be of just sufficient width to serve as a partition, by which the upper portion of the lamp chimney will be divided into halves or channels. How is the flame affected by the introduction of this card diaphragm?

Suspend a very light feather over the mouth of the chimney by a thread or by holding it in forceps. How do the reverse movements of its two ends prove that two currents of air are now in motion, the one entering the chimney and feeding the flame, the other removing the products of combustion as they pass out of the chimney.

(*B*) (1) Arrange three tapers (*a*), (*b*), (*c*), on a small bed of alplastine.

Cut (*a*) to measure about 10·5 cms. (4 in.) in length;
(*b*) to measure about 8 cms. (3 in.);
(*c*) to measure about 4 cms. ($1\frac{1}{2}$ in.).

Light them, and cover them immediately with a large bell-jar, from which the stopper has been removed.

Insert the thin end of a wooden wedge under the base of the bell-jar, pushing it further home as the flames

become dim. Notice the order in which they become affected, and the result of gradually admitting a larger volume of air.

Take a second wedge and introduce it under the opposite side of the jar from the first. Does this improve the character of the flames in regard to colour, steadiness and volume? Can the wedges be regulated is such a way as to secure a bright flame in each taper?

(2) Repeat the experiment twice, but use only two tapers on the first occasion and one on the second.

Make a note upon the number of minutes that bright steady flames are maintained in each case when the wedges are adjusted as in (1).

Do the results throw any light upon the statement that certain proportions ought to be maintained (*a*) between the areas of the inlets and outlets for air in occupied rooms, and (*b*) between these aids to ventilation and the number of persons in a room?

(*C*) Support in alplastine two tapers of the length directed in (*B*) (1), (*a*) and (*c*).

Take a piece of glass tubing about 15 to 20 cms. (6 to 8 ins.) long, with a diameter of at least 2 cms. ($\frac{3}{4}$ in.); fix this air-tight with alplastine in the mouth of the bell-jar, so that the portion of tube within the jar reaches below the level of the longer taper. Light the tapers, cover them with the jar, and in order to admit air from below insert the wooden wedges as in (*B*) (1).

What lesson does the result teach upon the most desirable position for foul air outlets in a room when the inlets for fresh air are low down?

Caution.—Secure that the air is renewed in the bell-jar between each stage of these experiments. A speedy and simple way to ensure the removal of the exhausted air is to stuff the bell-jar with a clean cloth once or twice in succession.

(*D*) Carry out the following observations with the assistance of a model constructed as in *Fig.* 110:—

Close all the apertures with well-fitting rubber corks.

(1) Stand three short tapers in the compartment marked (I); light them, shut the box and note the time which elapses before the tapers (i.) burn dim or smoke, (ii.) become extinguished.

(2) Open the box, thoroughly air it by removing all the corks and blowing forcibly with bellows through (A).

Repeat (1), but place three more lighted tapers in compartment (II) in addition to those which should be relit in (I).

(3) Is the time during which the tapers burn materially affected by this addition to their number?

Renew the air in the box as directed in (2), then light the tapers in (I) but leave (A) open. After 10 minutes light the tapers in (II) by introducing a taper through (E) or (F).

Which tapers are the first to burn dim or flicker?

(4) Try the effect upon the six flames of removing the corks from the apertures in the following order:—(B), (C), (D), (E), (F).

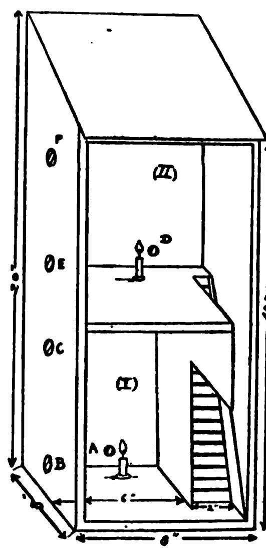


FIG. 110.

Do your observations corroborate the following statements?—

(*a*) That a supply of air is necessary to combustion and that imperfect combustion precedes extinction by a considerable time.

(b) That the greater the number of lights the quicker their extinction in the absence of a fresh supply of air.

(c) That even a small inlet for air exercises a beneficial effect, and enables combustion of a feeble type to be maintained.

That the addition of an outlet of a size equal to the inlet much more than doubles the effect upon the flame, as shown by an increase in its size and brilliance.

(d) That an inlet at a higher level than the outlet, or *vice versa*, brings about a far more efficient change of air in a confined space than when the two are on one level, and that with abundant and suitably arranged inlets and outlets combustion can be maintained, so long as the other conditions upon which it depends are fulfilled.

NOTE.—Tapers are used in this experiment for the sake of convenience to illustrate the results of animal respiration.

It is well to revive the memory of pupils upon the characteristics and properties of air by repeating and discussing the significance of the experiments in Part I., "*Conditions by which Life are Affected,*" *IV., page* 38, and "*Characteristics of Air,*" *pages* 43—60.

A house may be aptly compared to a closed box in which more or less stagnant air is enclosed, of which the purity is being continually vitiated by human respiration, by the products of the combustion of gas, coal, candles or lamps, and by emanations from the bodies, clothes and excretions of the inhabitants, as well as from the sinks, baths or sanitary fittings designed to remove organic matter from the premises.

Other impurities are usually present in consequence of the putrefactive processes active in ill-kept sculleries, dustbins or backyards, while dust, composed of organic or inorganic constituents, is a constant source of impurity in dwelling houses. An analysis of dust collected in a lady's bedroom shortly after a thorough "spring clean" gave the following results:—

Organic matter ..	52·6%
Inorganic matter ..	43%
Moisture	4·4%

The constituents of the organic matter (epithelial cells, animal and vegetable fibres, pollen spores, etc.), were described as "an excellent manure."

The air in an ordinary room contains about 35,000 dust particles per cubic centimetre, those in the air of a backyard may vary from 300,000 to 500,000, these include the ultra microscopic "dust," which is outside the housemaid's province and is probably of meteoric origin.

The number of organisms (moulds, yeasts, and bacteria), is, however, quite limited, from 1 to 22 per litre of air in a clean, well-ventilated room.

Dust and moisture are introduced from outside, or are produced by domestic processes within to an extent but little realized.

The removal of all impurities of a gaseous character is the special province of ventilation, which amounts in its simplest terms to a constant change of air without draughts.

Some active force is necessary to bring about the movement implied in this change of impure for pure air. There must be a far greater change than the mere oscillation of the gaseous contents which would result, if variations of temperature occurred in any given volume of air enclosed in a box. To meet this need, inlets and outlets are provided in every room, usually in the form of windows and chimney flues.

This fact is of such importance that the Model Building Bye-Laws of the Local Government Board require that for the ventilation of rooms without fireplaces or flues such rooms must be provided with a special air shaft or aperture, which shall provide an unobstructed sectional area of at least 645 square cms. (100 sq. ins.), to serve as an outlet for foul air.

The ordinary chimney flue usually measures 35 × 22·5 cms. (14 × 9 ins.), giving a sectional area of 1,225 sq. cms. (126 sq. ins.); thus the special aperture should consist of a grating in the wall or chimney stack measuring 25 × 25 cms. or 30 × 22·5 cms. (10 × 10 ins. or 12 × 9 ins.).

An outlet for foul air is of equal importance with an inlet for fresh air. Its dimensions should be at the rate of 154·8 sq. cms. (24 sq. ins.) per head; having the inlet larger than the outlet minimizes draught. Inlets may be near the floor if the entering air be warm, but if its temperature be not raised they should be at least 1·52 metres (5 feet) above floor level. It is better to have several small rather than one large opening.

For small rooms the chimney is the best outlet; all outlets should be placed at the same level in a room.

It has been calculated that an adult inhales about 11,700 litres (2,600 gallons) of air in twenty-four hours, which would equal a weight of 15 kilos (34 lbs.), or from 22 to 30 cubic inches at each respiration. Upon this basis an estimate can be formed of the quantity of fresh air required per hour by each occupant of a room.

Prominence is given to most of these points in the following experiments.

II.—Formula by which to Calculate the Amount of Fresh Air Required per head per hour (Professor de Chaumont).

(1) The formula is expressed as follows:—

$$\frac{A}{B - C} = D$$

$A =$ the quantity of carbon dioxide gas given off per hour per head.

$B =$ the proposed permissible maximum quantity of carbon dioxide in the air of the room per 28·31 cubic metres (1,000 cubic feet) of air. (This gas, though not usually present in proportions sufficient to be itself actively injurious, is nevertheless the accepted gauge of the presence of other highly injurious atmospheric impurities, such as organic matters, sulphurous acids, etc., on account of the ease with which its percentages can be estimated).

$C =$ the amount of carbon dioxide present in every 28·31 cubic metres (1,000 cubic feet) of fresh air.

$D =$ the amount of fresh air required per head each hour to maintain the standard quantity B expressed in cubic metres or in thousands of cubic feet.

An average adult exhales 0·6 cubic foot of carbon dioxide per hour, which authorities regard as the amount permissible in a room consistent with efficient ventilation. 1,000 cubic feet of pure air contain 0·4 cubic foot of carbon dioxide, to

which but 0·2 cubic foot can be added if the standard permissible impurity is not to be exceeded. The formula works out, therefore, to the following results:—

$$\frac{A}{B - C} = \frac{0{\cdot}6}{0{\cdot}6 - 0{\cdot}4} = D = \frac{0{\cdot}6}{0{\cdot}2} = 3{,}000 \text{ cubic feet of air}$$

which are needed per head per hour.

Now the average adult at rest expires from 22 to 30 cubic inches of air eighteen times a minute, which equals 23,760 cubic inches per hour, such expired air contains 4·4% carbon dioxide which amounts to 0·6 cubic foot per hour.

The cubic space per head in this climate should be in the proportion of one-third of the required air space, for it has been found experimentally that with ordinary appliances, and under the average atmospheric conditions in England, the air of a room cannot be changed more than three times an hour without a draught.

(2) Variations upon the same formula enable calculations to be made of the number of cubic feet of fresh air which are delivered per head per hour, and of the probable condition of the atmosphere of a room to which a given quantity of air is being supplied.

In the first case the quality of the air must be tested (*see* VII. (*A*) (*B*)), and the actual degree of impurity will replace in the formula the maximum permissible impurity represented by *B*.

If, for example, the proportion of carbon dioxide present amount to 1·2 the formula will work out as follows :—

$$\frac{A}{B - C} = D \text{ or } \frac{0{\cdot}6}{1{\cdot}2 - 0{\cdot}4} = {\cdot}75.$$

That is, 750 cubic feet of fresh air are being admitted to the room each hour.

In the second case the formula must be transposed as follows :—

$$\frac{A}{D} + C = B.$$

Here A represents the number of people in the room multiplied by their contribution to its atmospheric impurities, and D represents the assumed amount of fresh air supplied per hour.

$$\text{Thus } \frac{4 \times 0{\cdot}6}{1{\cdot}5} + 0{\cdot}4 = 2.$$

Here 1·4 parts of carbon dioxide per 1,000 volumes of air are present in excess of the amount considered permissible in dwelling houses.

NOTE.—By good ventilation most authorities mean less than 0·7% of carbon dioxide gas per thousand cubic feet.

Air containing 4 or 5 % of carbon dioxide causes a sense of oppression, with headache, distress, and perhaps coma.

III.—Cubic Space and Air Supply.

MATERIALS: *Strips of cotton velvet or bunch of cotton waste.*

APPARATUS: *Foot rule.*

(*A*) Take the dimensions of the following rooms :—

(*a*) your class room,
(*b*) your dining room,
(*c*) your bedroom,

and calculate the cubic capacity of each, the amount of air-space per head if occupied as suggested below, and the frequency with which it would be necessary to renew the air in each room if each occupant must be allowed 56·630 cubic metres (2,000 cubic feet) of fresh air per hour :—

(*a*) when occupied by 45 persons,
(*b*) when occupied by a family of six persons,
 (i.) during daylight,
 (ii.) with 3 gas lights,
 (iii.) 3 electric lights.

NOTE.—A batswing or fish-tail gas burner consumes on an average about 4 cubic feet of coal gas per hour, which amount furnishes some 2 cubic feet of carbon dioxide gas in that time. It is generally believed that an allowance of 1,200 cubic feet of fresh air should be made for every cubic foot of gas consumed.

(*c*) when occupied by one person.

(*B*) Measure the areas of the usual air inlets in these rooms and compare them with the areas of any outlets which are provided for the escape of air; then estimate the proportion they bear to the number of occupants, if each is entitled to an allowance of 24 square inches for inlet and a similar amount for outlet.

NOTE.—The following rules and examples will enable these calculations to be made with accuracy.

In all questions of mensuration by beginners, rapidity and ease of calculation will be materially assisted if the figure under solution be accurately plotted, preferably on squared paper, to a fairly large scale of equal parts.

(1) To find the area of a rectangle. Length × breadth = area.

To find the area of a triangle. Base × perpendicular height, divide by 2.

To find the area of a trapezoid. Multiply the sum of the two parallel sides by the perpendicular distance between them, divide by 2.

To find the area of any rectilinear figure. Divide the figure into triangles by lines from its angles, calculate the area of each triangle and add the results.

To calculate the length of a side of an octagon. Multiply the diameter by ·4142136.

To find the area of a circle. Multiply the square of the diameter by ·7854; or multiply the radius by the circumference and divide by 2.

(2) To find the cubic capacity or volume of a cube, a prism or a cylinder. Multiply the area of the base by the perpendicular height.

To find the cubic capacity of a pyramid or cone. Multiply the area of the base by $\frac{1}{3}$ of the perpendicular height.

To find the volume of a prismoid or frustum of a wedge. Add four times the area of a section parallel to the base and equally distant from both ends to the

sum of the areas of the two ends. Multiply the sum by $\frac{1}{3}$ the perpendicular height, the product will give the volume.

To find the volume of a sphere. Multiply the cube of the diameter by ·5236, the product will be the volume.

It is obvious that calculations for rectangular rooms are quite straightforward, but if a rectangular room has a sloping ceiling the procedure must be varied; the length must be multiplied by the breadth and by the *mean* height. To obtain this, measure both the maximum and minimum heights of the room, add the two together and divide by 2. For all irregular solids this rule is the same, divide them into their simple component figures and add together the cubical contents of each of these.

The total floor space of a room should be $\frac{1}{12}$ of the total cubic capacity.

Example.—To calculate the cubic capacity of a room 11 ft. high, and 30 ft. square, with a semicircular bow 20 ft. wide. Make a sketch-plan figured with the dimensions and particulars just furnished, the following results will be then easily obtained.

The floor area of the room = (area of the rectangular part + the area of the bow) = (30 × 30 ft.) + ($\frac{1}{2}$ (diameter of bow)^2 × ·7854) = 900 + 157·08 = 1,057·08 square feet.

Cubic capacity = floor area × height = 1,057·08 × 11 = 11,627·88 cubic feet.

Since, as a fact, each individual requires 84·945 cubic metres (3,000 cubic feet) of fresh air per hour, and since the air in a room, unless artificially warmed, cannot be changed more than three times an hour without causing discomfort from draughts, the amount of cubic space per head in an occupied room should average 28·315 cubic metres (1,000 cubic feet), free from furniture or other encumbrances.

(The amount of air space occupied by an adult body is 4 cubic feet and it is also customary to allow 10 cubic feet for a bed, the volume of other furniture can be estimated by measurement.)

What deductions from the calculations made in (*B*) would become necessary under these heads.

In practice, the following insufficient allowances of air-space per head are permitted:—

Poor Law Infirmaries	850 to 1,200	cubic feet.
Barracks	600	,,
Workhouses	300	,,
Common Lodging-houses ..	300	,,
Non-Textile Workrooms.. ..	250 to 400	,,
Schools (Secondary)	180	,,
,, (Elementary)	100 to 130	,,
,, Canadian..	240	,,
Canal Boats	60	,,

(*C*) See that the windows or other provision for ventilation are arranged as is customary in the room under examination, and again measure the superficial area of their openings.

Determine what the size of these should be, bearing in mind the two facts that—

(1) the amount of air required depends upon the number of occupants, and (2) that the amount admitted depends upon its velocity, which in this climate cannot comfortably exceed 1·25 metres (4 feet) per second. It is usual, therefore, to calculate on an allowance of 156 sq. cms. (24 sq. ins.) per head fo inlets, and an equal amount for outlets, making a total of $156 + 156 = 3{\cdot}12$ sq. decimetres ($24 + 24$ sq. ins. $= \frac{1}{3}$ sq. ft.).

To obtain a rough idea of (2), ignite several strips of cotton velvet or a bunch of cotton waste and hold the smouldering mass close to the apertures in the window, fireplace, Tobin tubes, or other ventilation appliances. The direction of ıe air currents, whether inward or outward, will be shown by the direction taken by the smoke, the velocity of the currents will be generally indicated by its

rate of movement. When satisfied on this point, extinguish the smouldering substance, light a candle and hold the flame close to the key-hole, at the top and bottom of the door, and at different points near the window-frames and other cracks or crevices in the walls or floor of the room.

Observe by the inclination of the flame where air is entering or leaving a room.

Confirm your deductions as to the adequate or inadequate ventilation of the different rooms as follows:—

After at least one, or preferably two, hours of occupation leave the room, close the door and go into the open air, make several deep respirations, return directly to the room and notice the impression of its atmosphere received on entering. If there be any close odour or sense of depression no further proof is needed that its ventilation is defective.

NOTE.—The rate of the air current in a room is measured scientifically by an instrument known as the *anemometer* or air meter, which consists of revolving vanes, like the arms of a windmill, attached to a registering dial. If this instrument be employed for the purpose, several observations should be made under due precautions and then an average should be struck.

It will be found that, as a rule, the provision for ventilation in rooms is most inadequate and is responsible for much languor, depression and unrecognized discomfort, while the poisonous quality of the air exercises a cumulative effect on human vitality.

It is customary to disregard a greater height than 4 metres (13 feet) in a room, as the air movements above that level prove of little value under ordinary arrangements of inlets and outlets.

Animal exhalations hang near the level of the head of the occupants or diffuse very slowly, a fact which partly accounts for the foul atmosphere in churches and concert halls. When windows are not carried up to the ceiling an inverted lake of impure air is formed, saturated with organic moisture, more especially in the evening when gas or oil lamps are in use. Though large rooms do not obviate the necessity for constant ventilation, they diminish the difficulties.

Recommend for small bedrooms (where the bed is necessarily close to the window), that a screen be placed at night between the bed and the window to protect the head or feet of the sleeper; or suggest that a strip of unbleached cotton wadding be fixed over the opening between the sashes of the window when a Hinckes-Bird's Board is used (*Fig.* 109, *a*); or if there be no fireplace, and a Sheringham valve or other ventilating valve be fixed in the wall in compliance with the Building Bye-Laws of many Local Authorities, advise that a lid of wire gauze, or of card perforated with numerous holes, be laid over the large aperture of the open valve. The air is broken up into numerous small streams as it enters through the wadding or perforated lid, thus minimizing the discomfort experienced from a large current of cold air pouring into a room.

IV.—Shape and Advantages of Different Forms of Air Inlets and Outlets.

MATERIALS: *Models of Hinckes-Bird's Window-Board, Casement Board, Sheringham Valve, Tobin's Tube, Mica Flap-Ventilator, Cooper's Ventilator; Ellison's Conical Air-brick; sheets of paper; candle.*

APPARATUS: *Bellows.*

(*A*) Make a cone with the square of paper provided. Light a candle and blow through the cone, (*a*) with apex towards the flame, (*b*) with the base toward the flame.

Keep the same distance from the candle in each case.

Compare the paper cone with an Ellison's Conical Air-brick.

Repeat the experiment, but blow air with bellows towards the candle flame through the brick instead of through the cone.

What principle do the results illustrate; what is the total area of the several openings?

(*B*) Examine models of the following apparatus in common use for purposes of ventilation in houses, schools, halls, etc.

Consider in what way each is designed to promote this end, by serving either as an outlet or an inlet for air; (*See Fig.* 109).

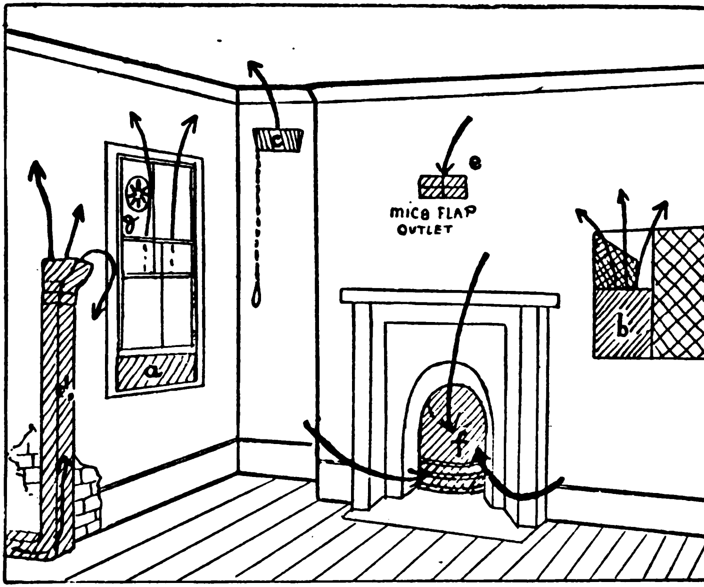


FIG. 109.—Room fitted with Specimens of Various Forms of Domestic Ventilators.

(1 *The Hinckes-Bird's Window-Board,* a piece of board or plate-glass the width of the window and from 7·5 to 15 cms. (3 to 6 in.) deep, introduced under the lower sash, which is closed down upon it. (*Fig. a.*)

(2) *The Casement Window-Board,* also made either of wood or plate-glass framed in wood, the width of the window and from half to two-thirds its height. (*Fig. b.*)

(3) *The Sheringham Valve,* an iron box fixed in the wall of a room near the ceiling, of which one side (that exposed to the outside air), consists of an iron grating, and the other of a valve which opens into the room; this can be opened or closed at will by means of a string and pulley. (*Fig. c.*)

(4) *A Tobin's Tube,* or hollow pilaster, 2 metres (6 ft. 6 in.) high, supported against the wall; the base is bent at right angles and carried through the wall to the outer air, this end is covered with a grid. The tube may be wholly or partially closed by means of a valve within controlled by a handle on the exterior of the tube. (*Fig. d.*)

(5) *A Mica Flap-Ventilator* which should be fixed in the chimney breast near the ceiling. It consists of an iron frame across which lie iron rods; from these thin mica flaps are suspended which can only open in the direction of the chimney. (*Fig. e.*)

(6) *The Chimney.* Why is the action of this outlet so much increased when a fire is burning in the grate? (*Fig. f.*)

(7) *Cooper's Ventilator.* A circular plate of glass which moves on a pivot passing through its centre and also through the pane of glass in the window or aperture to which it is to be fixed. Holes are made in this pane to correspond with those in the moveable disc. (*Fig. g.*)

Note.—Ellison's Bricks, the Window Boards (*a*) and (*b*), Tobin's Tube and Cooper's Ventilators serve as air inlets, the construction and arrangement being designed in each case to introduce fresh air above the heads of the occupants of a room and to promote its diffusion, in order to minimize sensations of draught.

The Sheringham Valve, Mica Flap-Ventilator and chimney should act as outlets for exhausted air, though the action of the first two is unfortunately liable to be reversed in obedience to the law of thermal convection, under certain conditions of wind and atmospheric pressure.

Variations of these different appliances are on the market, but for domestic purposes ventilation by means of suitably arranged windows, *Fig*. (*a*) and (*b*), and fireplaces is both cheaper and more efficient.

The window fittings can be made for a few pence; they may be bolted into the frame on each side and, when made of glass, are free from any objection on the score of diminishing light or of obscuring the view. The casement window can be adjusted as usual to any desired inclination according to wind and weather; air will enter only above the fitting, a great advantage during nine months in the year in this country, when casement windows are difficult to manage..

An ordinary chimney flue with a superficial area of 4·645 sq. decimetres (72 sq. in.), with a probable velocity of 177 metres (600 feet), would represent a withdrawal of 91·43 metres (300 feet) per minute. In order that the velocity of the entering air may not exceed 1·52 metres (5 feet) per second the inlet from which the fire draws this supply of air should have a clear opening of not less than 9·290 sq. decimetres (144 sq. ins.), that is 60 × 45 cms. (24 × 18 ins.) outside and 37·50 × 30 cms. (15 × 12 ins.) inside.

It is calculated that a fire in an ordinary grate requires from 283·15 to 424·725 cubic metres (10,000 to 15,000 cubic feet) of air per hour, it serves consequently to furnish a sufficient air supply for four or five people.

Attention must, however, be directed to the fact that *downdraughts* are liable to occur if flues are of unequal length, unless each room receives an adequate and separate supply of air direct from the exterior.

Even when all the flues are carried to the same height they may draw on one another (unless there be a separate air-supply to each apartment), if there be a variation of temperature in the several flues associated with air communication at the base, a condition usually present in an ordinary house where the rooms open into a common hall.

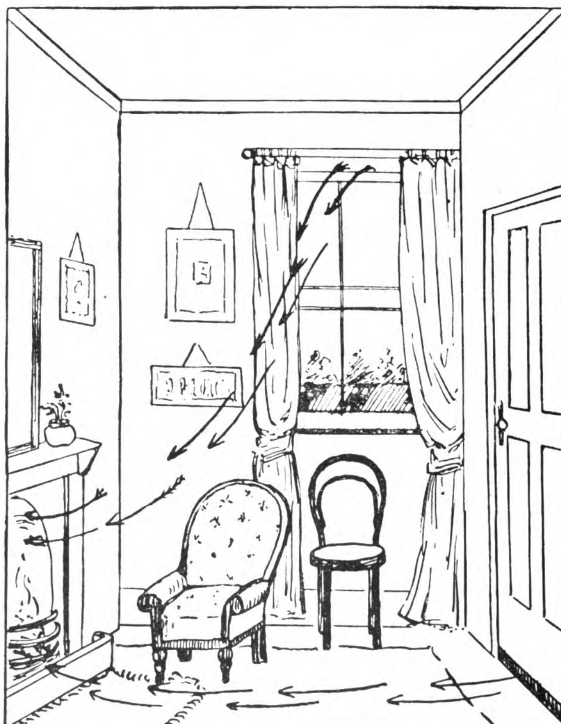


FIG. 110.—Badly Ventilated Room.

To minimize draughts, adequate provision must be made to supply the demand for air, otherwise the discomforts will be experienced which are represented in *Fig.* 110.

One of the most satisfactory methods of supplying pure air and avoiding draughts is to heat the incoming air by means of what are known as Ventilating Grates, the principle of which is shown in *Figs.* 111 and 112.

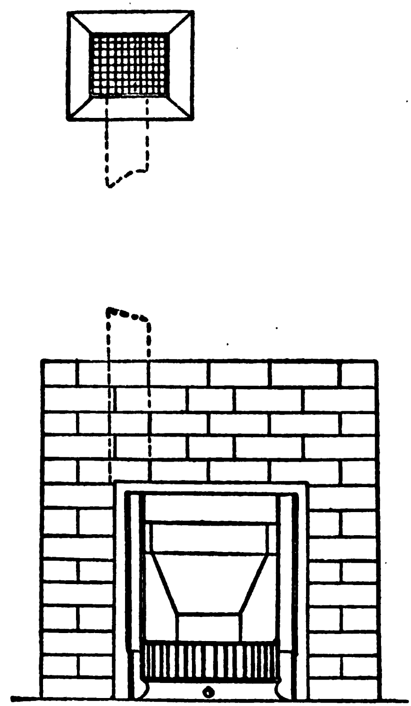


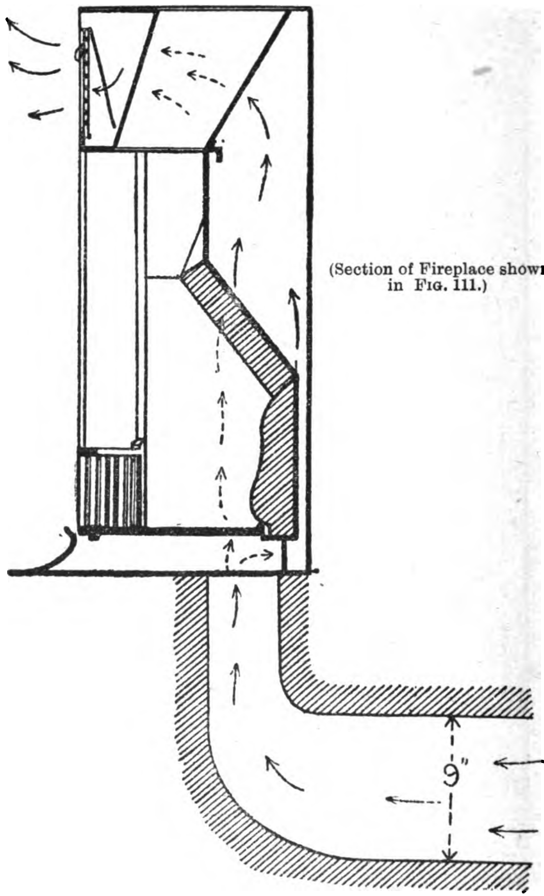
Fig. 111.*

The great advantage of these grates is the arrangement made for the fresh warmed air to be introduced into the room at from 5 to 6 feet from the floor. The air is drawn through a shaft connected with the outside air, passes up in close contact with the heated fire-brick, of which the "rifle back" of the fireplace is made, and is delivered through a grid into the apartment, the temperature meanwhile being raised to an agreeable degree when there is a fire in the grate. Thus

* Reproduced by kind permission of the Teale Fireplace Company.

pure warm air diffuses through the room without causing any sensation of draught.

The more general adoption of such improvements, however, depends upon the attitude of the public towards this important and complex subject of ventilation.



(Section of Fireplace shown in FIG. 111.)

FIG. 112.*

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(*C*) (1) Roll a sheet of paper into a narrow tube; light a candle and blow down the tube when it is directed at the flame. Observe the degree to which the flame deflects.

(2) Bend the tube to a right-angle at about half its length; repeat the test with the flame. Is the volume of air much or little diminished?

(3) Bend the paper tube a second time to a right-angle. In what proportion do you consider the current of air to be diminished as it passes from your mouth down the tube to the flame?

Repeat the experiments with paper tubes of greater and less diameter and length. What do the results suggest on the influence upon ventilating shafts of length, width and shape?

NOTE.—If a tube is bent at right angles, half the air current is lost; while if it is bent twice at right angles only one quarter of the air current is obtainable.

The chief causes of obstruction to the free passage of air through inlets and outlets are:—

(1) Too great length of shaft compared with the width;
(2) Irregularity of shape of opening;
(3) Reduction of the total air space by dividing the opening into too many parts;
(4) Accumulation of dust, so that the opening is clogged.

Actual velocity is reduced from one-fourth to one-half of the theoretical velocity by the friction or resistance offered by the air-flue. This increases directly with the length, and inversely with the area of the flue.

The direct causes of friction are the length of the tube or shaft, the size of the opening, the shape of the opening, any angles in the tube, the presence of soot or dirt.

If the inlets are rather larger in proportion than the outlets there is less risk of draughts, and several small inlets near each other are preferable to one large one.

V.—Gaseous Diffusion.

MATERIALS: *Candle; tapers; brown paper or cotton waste; vaseline.*

APPARATUS: *Plate; lamp chimneys; wooden box; bellows.*

(*A*) Repeat "SOME CHARACTERISTICS OF AIR," II. (*E*), (1) (2), *page* 48.

What property of gases does this show? What principle of ventilation do the results illustrate?

(*B*) *Aspiration.*

(1) Place some smouldering brown paper or cotton waste on a plate under a glass lamp chimney. Blow across the top of the chimney with a pair of bellows. Observe the movement and direction of the smoke. How is this to be accounted for?

(2) Fit two lamp chimneys (*a*) and (*b*) into the lid of a wooden box, which should measure 25 × 10 × 7·50 cms. (10 × 4 × 3 in.) Fix a taper under each aperture into which the lamp chimneys are fitted, light them and cover with the lid of the box carrying (*a*) and (*b*).

Hold a piece of smouldering brown paper over (*a*). In which direction does the smoke move?

Blow forcibly across the top of (*b*) with the bellows. How does this affect the direction of the smoke?

(3) Light the candle under (*b*) again hold the smouldering paper over (*a*). Is the direction taken by the smoke similar to that observed in (2).

How do you account for these phenomena?

NOTE.—Reference has already been made to the fact that every gas diffuses at a rate which is inversely proportional to the square root of its density (*page* 47), but if two gases are of the same density they show little tendency to mix. Where however the densities vary, in consequence of variations in the character of the gas or in the temperature outside or inside the building, they intermingle with great rapidity.

The action of wind affords a second valuable agency in what is called "natural ventilation," it may act by blowing freely through open doors and windows, or by blowing across the tops of chimneys or tubes and so causing a current of air to flow at right angles to itself up these channels.

VI.—Sources of Impurity.

MATERIALS : *Small pieces of coal; magnesium ribbon; taper; lamp-oil; hydrochloric acid; lime-water.*

APPARATUS : *Glass jars; glass tubing; T-shaped glass joint; gas-jars; glass covers; c.c. measure; beehive cell; beaker; thermometer; deflagrating spoon; Bunsen burner.*

(*A*) *Respiration* (*cf.* "SOME CHARACTERISTICS OF AIR," IV. (2), *page* 53.)

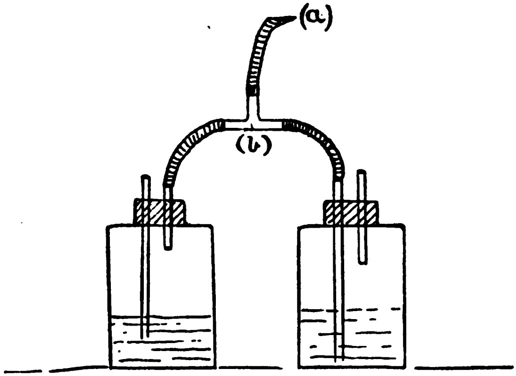

FIG. 118.

(1) Fit up two jars as figured and connect the glass tubing with the T shaped glass joint (*b*). Pour equal quantities of lime-water into both bottles. Apply the lips to the glass mouth-piece (*a*), pinch the nostrils to close them, then inhale and exhale several times into the jars without removing the lips from the mouth-piece. Do you observe any difference in the appearance of the lime-water in the jars? What proof does this afford of the effect of each additional person present upon the atmosphere of a room or hall?

(2) Refer to *page* 41, and arrange a gas-jar full of water on a beehive cell as shown in *Fig.* 7.

Take a glass tube bent twice at right angles similar to that in *Fig.* 7, apply one end to the lips, insert the other end beneath the water in the aperture of the beehive cell. Proceed to collect a gas-jar full of expired breath under water, expiring through the tube as deeply as possible. Fresh air must be inspired through the nose.

When all the water is displaced from the jar, withdraw the glass tube and fix a strip of magnesium ribbon to a deflagrating spoon. Kindle the ribbon and plunge it into an *empty* gas-jar until combustion has ceased.

Carefully raise the jar of expired air from the water and repeat the ribbon test. Then add some dilute hydrochloric acid to the ash in both jars. Shake them well and compare results. What does this experiment prove with regard to the increased impurity of expired over atmospheric air?

(3) Hold a thermometer at arm's length. What temperature does it record?

Next hold it close to the mouth and breathe upon it. What does it now record? Observe the rise of the mercury, due to the fact that the temperature of the breath is so much above that of the atmosphere; *cf.*, the heated air in rooms occupied by many people for several hours.

Breathe into a *cold* glass beaker. What do you observe? Does this assist you to explain the source of the moisture which condenses in cold weather upon the glass surfaces in crowded vehicles or halls?

(*B*) *Combustion.*

(1) Pour a little lime-water into a gas-jar. Does any change take place in its appearance after 5 minutes?

Pour a few drops of lamp-oil into a deflagrating spoon, lower it into the gas-jar, and ignite the vapour of the oil with a taper. Is any change to be observed in the lime-water after combustion has ceased?

(2) Repeat (1), but replace the oil in the second part of the experiment with a small piece of coal, which must be ignited before it is lowered into the gas-jar.

(3) Close the air inlets of the Bunsen burner with the sliding collar in order to produce a luminous flame. Turn this low and hold a gas-jar over it. When the flame almost ceases to be visible remove the jar, slip a greased glass cover quickly over the mouth, and turn the right way up. Pour in a little lime-water. What is proved by these observations? (*cf.*, "CHARACTERISTICS OF AIR," IV. (1), *page* 53).

VII.—How to Estimate the Condition of the Atmosphere.

MATERIALS: *Muslin; string; stamp paper; mercury; lime-water; baryta solution; phenol-pthalein; alcohol; red ink.*

APPARATUS: *Glass flasks with stoppers* (*see* VII. (*A*) (1)); *pipette; c.c. measure; thermometers; glass tubing; large and small glass funnels; Dr. Scurfield's Ventilation Indicator; retort stand or wooden filter stand.*

(*A*) *Test for the Amount of Carbon Dioxide Present.*

(1) Take six glass flasks (*a*), (*b*), (*c*), (*d*), (*e*), (*f*), fitted with stoppers and of the following capacities:—

(*a*) 100 c.c. = 3·52 oz.
(*b*) 200 c.c. = 7·04 oz.
(*c*) 250 c.c. = 8·8 oz.
(*d*) 300 c.c. = 10·56 oz.
(*e*) 350 c.c. = 12·32 oz.
(*f*) 450 c.c. = 15·84 oz.

(2) Fill each flask with water, then empty and drain dry. This procedure ensures that they shall be filled with the air of the room in which the experiment is to be carried out.

(3) Draw up 15 c.c. ($\frac{1}{2}$ oz.) of clear lime-water into a glass pipette and empty it into (*a*). Replace the stopper and shake. If any turbidity results, the amount of carbon dioxide present equals 1·6 parts in 1,000 volumes of air.

(4) If no change takes place in the appearance of the lime water repeat (3), but substitute (*b*) for (*a*). Turbidity here would indicate 1·2 parts of carbon dioxide in the air.

(5) Continue the experiment until turbidity results in the flask tested. If this occur in (*c*) it would signify 1 part per 1,000, in (*d*) it would represent ·8 parts, in (*e*) ·7 parts and in (*f*) less than ·6 parts, or the equivalent of the permissible impurity in occupied rooms.

NOTE.—To judge of this turbidity the late Professor Jacobs recommended that a piece of stamp paper be marked with a lead pencil on the adhesive side, which should then be attached to the flask near its base. If the mark be invisible after the lime-water has been well shaken in each flask, the fact of turbidity is established.

(*B*) *Dr. Scurfield's Ventilation Indicator.*

(1) Lift the apparatus from the tin case and fill the aspirator, round which the glass tubes are fixed, with water. Fill each tube with the same quantity of the pink solution of baryta and phenol-phthalein.

(2) Place the instrument in the open-air on a window-ledge or chair and connect one tube with the aspirator by means of the rubber tubing.

Place the case below the instrument in such a position as to catch the water when the tap near the base is turned on.

Notice any change in the colour of the pink solution as the air bubbles through the tube.

If any colour remain in the solution when the aspirator is empty, refill the instrument and repeat the process until the solution is decolorized.

Watch carefully, and instantly turn the tap by which the water escapes when decolorization is complete.

Note the level of the water in the aspirator, which is registered on the gauge above the tap.

The quality of the outside air may be taken as the standard of purity with which to compare subsequent results.

(3) Refill the aspirator from the water in the case, disconnect the decolorized tube, carry the apparatus into

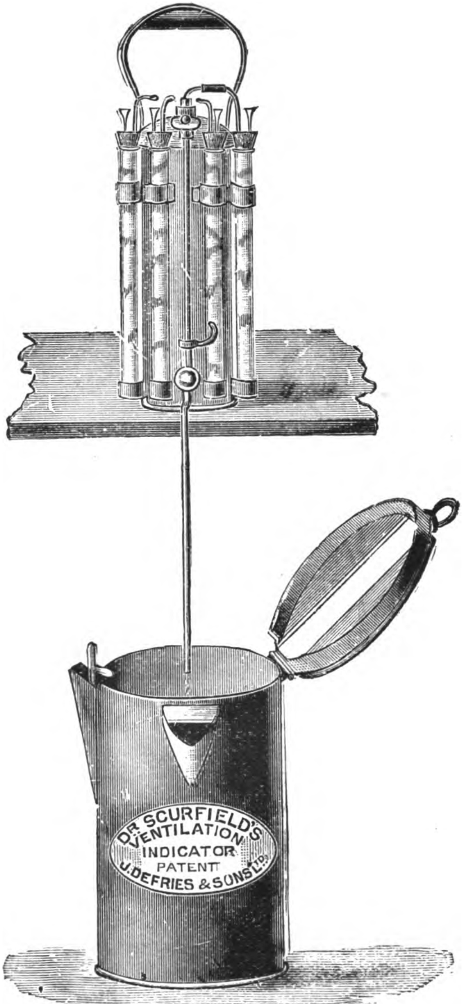

FIG. 114.*

* Reproduced by kind permission of Messrs. J. Defries & Sons, Ltd.

the room where it is desired to test the quality of the air, connect the aspirator with a second tube and repeat (2) until the solution is decolorized.

Is the amount of air necessary to effect this less or more than in (2), as shown by the amount of water which has been run off by the aspirator?

(4) Repeat (3) in various parts of the room or in a series of rooms, and observe the relative impurity of the air according to the amount which must bubble through the solution to cause decolorization.

NOTE.—The apparatus consists of an outer metal case of cylindrical shape, about 33·5 cms. (13 ins.) high and 17 cms. ($6\frac{3}{4}$ ins.) in diameter. Within is an aspirator, which holds 1·75 litres (2 pints) of water, supplied with a vertical gauge, surrounded by seven tubes, all containing exactly the same quantity of the same pink solution of baryta and phenol-phthalein. Each tube can be connected in turn with the aspirator, so that as the water is run off from the apparatus an equivalent amount of air bubbles through the pink solution in the tube, which loses its colour quickly or slowly according as there is much or little carbon dioxide in the air. The case is used for catching the water and for refilling the aspirator when necessary.

When the decolorization is complete, the tap is turned off, and the amount of air that has been necessary to effect the decolorization is shown by the amount of water that has been run off from the aspirator.

In order to get all the tubes decolorized to the same extent, it is advisable when comparing them to look through the depth of the column of contained fluid. For example, one tube is decolorized in the outside air and it is found that 1·8 aspirators full of air are necessary to do this. A second tube is decolorized in the room under observation and it is found that 1·2 aspirators full of air are necessary to do this.

In such a case the amount of carbon dioxide in the air of the room is to the amount in the outside air as 1·8 is to 1·2; or, in other words, the air of the room contains half as much again carbon dioxide as the outside air. On the usual assumption that the outside air contains ·04 per cent. of carbonic acid, then the air of the room contains ·06 per cent., and the carbon dioxide due to respiratory impurity, etc., is equal to ·02 per cent.

If all the tubes are filled, a number of rooms can be efficiently tested very rapidly.

The following formula serves to ascertain the approximate quantity of carbon dioxide gas found in any room:—

$\frac{A \times 4}{B}$ = parts of carbon dioxide gas per 10,000 of air. A being the amount of outside air and B the quantity of inside air required to discharge the colour of the solution.

A fluid of conveniently deep colour for use in the tubes, may be made by adding about 40 minims of a saturated solution of baryta, containing an excess of undissolved baryta, and 60 minims of the phenol-phthalein solution to a pint of distilled water. If a deeper colour be preferred, more of the baryta solution must be used; keep in a stoppered bottle.

Standard solutions are unnecessary, the important point is to see that each tube is filled up to the graduation mark with the same solution.

When all the tubes have been decolorized, their contents may be mixed in a flask and the colour brought back by the addition of a suitable quantity of the baryta solution, the mixture is then available for use again. The presence of a small amount of carbonate of barium as the result of the previous experiment does not interfere with the test.

The aspirator may be also used for drawing a measured quantity of air through a weak solution of permanganate of potash when it is desired to gauge the presence of organic matter in the air of a room. In this case the pink solution will become brown, in proportion to the presence of a greater or less amount of organic impurity.

(*C*) *The amount of Water Vapour present in Air.*

Make as follows a Mason's Hygrometer, or Wet and Dry Bulb Thermometer.

(1) Take two exactly similar thermometers (*a*) and (*b*), of which the readings are identical. Record what these are. Suspend them side by side with string from the ring of a retort stand or from the horizontal arm of a wooden filter stand.

(2) Enclose the bulb (*b*) in a small square of muslin. Tie a narrow strip of the same material at the point where the square of muslin is secured above the bulb and dip the free end into a small vessel of water placed close to (*b*).

(3) Observe and record the reading of (*a*) and (*b*) at intervals of 5, 10, 20, and 30 minutes.

For how long are the records the same? What is roughly the difference between the two when no further change takes place.

Refer to "The Skin," I. (*C*), (1), *page* 199, for an explanation of the results which are observed.

Note.—If (*a*) registers 16·5° C. (62° F.), and (*b*) records 13·3° C. (56° F.), the humidity present in the air of the room is about 68 per cent. of saturation point.

This conclusion is reached by:—

(1) Finding the "dew point," which in this case would be 10·4° C. (50·84° F.).

(2) Getting the weight of moist vapour per cubic foot, which corresponds to this dew point from a table prepared for the purpose, in this case 4·21 grams (64·96 grains).

(3) Dividing this amount by 6·17, which is the corresponding vapour weight for the air temperature.

(4) Multiplying this by 100, the product is 68.

The phenomenon observed in a hygrometer are to be explained as follows:—

Heat is absorbed in consequence of the evaporation of moisture from the wet muslin round the bulb of (*b*), the mercury as a result registers a lower temperature than in (*a*). The difference between the two records depends upon and indicates the dampness or dryness of the air.

Evaporation is slow when the air is nearly saturated with moisture and ceases when it is completely saturated. Under such circumstances the readings will be nearly or quite the same. If the air be very dry evaporation from the moist muslin will be rapid, the absorption of heat will be also rapid, and consequently (*b*) will register a much lower temperature than (*a*).

In a ventilated room in this climate the "dry" bulb thermometer ought to register from 17·2° to 18·8° C. (63° to 66° F.) and ought not, if possible, to fall much below 15·5° C. (60° F.). The "wet" bulb ought to read 14·4° to 16·1° C. (58° to 61° F.), *i.e.*, the difference between the two thermometers ought not to be less than 2·2° C. (4° F.) or more than 4·5° C. (8° F.).

By the use of the Hygrometer (of which this is quite the simplest form), the amount of water vapour present in the air at any given moment can be registered ("*Air*," III. (*B*), (1) (2), *page* 52).

Water vapour absorbs not only the radiant heat reflected from the earth's service but a portion also of the heat in the sun's rays. The earth is kept much warmer by this means and the atmospheric temperature is far more equable in consequence.

Air may, and often does, *feel* damp when it actually contains far less water vapour than when it feels dry. The question is one really of relative humidity and temperature. When air at a given temperature actually contains considerably less water vapour than it is capable of holding *at that temperature* it feels dry, whereas when at the same temperature it is saturated to the extent of which it is capable *at that temperature* it feels damp. Consequently it is usual to express the amount of water vapour present in air in terms of this relative humidity, upon which, and not upon the actual quantity present, sensations of moisture or dryness entirely depend. If saturation point be represented by 100, from 65 to 70 per cent. of humidity is the proportion most agreeable to us in this climate.

To assist pupils to realize the relative proportion of moisture which is present in a given volume of air according to its temperature, draw a cube 1 metre square on the blackboard, and measure out the following quantities of water in a series of c.c. measures (*a*), (*b*), (*c*), (*d*).

Pour into

(*a*) 20 c.c. (308·64 grains); this represents the amount of moisture exhaled per head per hour, which suffices to saturate 90 cubic feet of air at a temperature of 17° C. (62·6° F.).

(*b*) 4·87 c.c. (75·153 grains) represents the amount of moisture present in a cubic metre of air saturated at a temperature of 0° C. (32° F.).

(*c*) 12·76 c.c. (196·81 grains) represents the amount present in a cubic metre of air at a temperature of 15° C. (59° F.).

(*d*) 33·92 c.c. (523·45 grains) represents the humidity of this volume of air saturated at a temperature of 32·2° C. (90° F.).

(*D*) *Atmospheric Pressure.*

Make a simple barometer as follows :—

(1) Take a glass tube (*a*) ·91 metre (1 yd.) long and ·6 cm. (¼ in.) bore, of which one end should be closed (this can be done if necessary in a blow-pipe flame). Fix a very narrow strip of gummed paper the whole length of the tube.

(2) Half fill a large glass funnel (*b*) with mercury, closing the neck with a firm wad of paper or wool.

Balance (*b*) in the ring of a retort stand so that the neck just clears the table.

(3) Insert a very small glass funnel (*c*) in the open end of (*a*), then fill (*a*) very slowly with mercury to within 1·25 cms. (½ in.) of its full length.

Close the end with the finger and tilt the tube up and down several times, until the small bubbles of air mixed up with the mercury are collected into one large bubble at the open end of the tube.

Hold it in a vertical position, remove the finger, replace (*c*) and fill (*a*) brimful.

It is well to perform the process over a tray in order to catch any mercury which may be spilt.

(4) Press the finger *very* firmly on the open end of (*a*), invert the tube and bring the end closed by the finger under the surface of the mercury in (*b*). When the tube is vertical remove the finger, and immediately clamp it to the retort stand.

What is the immediate result of removing the finger, does this explain the direction given in (2) to *half* fill the large funnel with mercury ?

(5) Mark the level of the mercury in (*a*) upon the paper scale and measure the distance from the table.

Release (*a*) from the clamp and gently slope the tube away from the retort stand.

Again mark the level of the mercury within the tube, at the same time measure accurately, with the assistance of your companion, the exact distance from the table to the level of the mercury on the scale.

Return the tube to its vertical position and repeat this measurement. Why is the distance from the table the same in the two cases? Repeat the experiment given under "Air," II. (*B*), *page* 46. Does this furnish any clue to the observations just made?

(6) Fix (*a*) in as upright a position as possible, then mark the level of the mercury in (*b*) as well as in (*a*).

Measure the column of mercury between the two points and mark these with red ink. Stand the apparatus aside and repeat this observation every day for a week.

Do the measurements always correspond, or to what degree do they vary?

Is there any connection between the weather and the character of the variations shewn by your record?

Note.—The principle of the barometer is that of a balance; in the one scale there is the column of mercury, in the other a column of air of the same sectional area as that of the mercury. If the air become heavier it can counterpoise more mercury and the barometer rises, if the weight of the air diminish, the barometer falls.

Aqueous vapour when present as an invisible gas is only $\frac{5}{8}$ as dense as dry air at the same temperature and pressure, for a given volume of water vapour weighs 9 where a similar volume of dry air weighs 14·4. Moist air is consequently much lighter than dry air.

Atmospheric pressure is affected by cyclones and anti-cyclones, by the transfers of air from hemisphere to hemisphere, by seasonal influences, and by the diurnal variations in temperature caused by the sun's rays, as well as by the degree of humidity present in the air at any given moment. All these causes, consequently, are responsible for variations in barometric records.

VIII.—Artificial or Mechanical Ventilation.

NOTE.—Artificial or mechanical ventilation is illustrated chiefly by two systems known respectively as the Vacuum and the Plenum. Of these the Vacuum system relies upon the *extraction of foul air* and is based upon the principle of the action of an ordinary fireplace, which, by heating a column of air, causes its expansion and displacement by a supply of fresh, cold air. The process of extraction may be effected (*a*) by the agency of heat, as it is in theatres, where lighted gaseliers near the roof are used to promote this method of ventilation, for the burning of 1 cubic foot of gas can lead to the discharge of several hundred cubic feet of air; the same method is still employed in mines and in some prisons; (*b*) by the use, in appropriate positions, of jets of steam; for one jet of steam can set in motion a body of air equal to 200 times its own size; exemplifications of this system are often found in factories; (*c*) by employing a fan or Archimedean screw to aspirate the air and so to cause a vacuum, a method of which examples are also found in mines, dusty mills, etc. There are many objections to this system, which is now increasingly replaced by the Plenum system, where propulsion instead of aspiration is employed to get rid of foul air.

In this case air is *driven mechanically* by bellows, pumps, or fans into proper channels. Many authorities consider it "the most perfect method of ventilation, as the air is under complete control in every way," and it has been largely adopted in many countries.

(*A*) *Inspection of a System of Mechanical Ventilation.*

The Plenum system has been adopted for use in schools in several towns in this country.

Explain the principles of the system to the pupils before the tour of inspection is made; *viz.*, that air, suitably warmed and filtered, is introduced into the building under a pressure which should suffice to propel it through every room and to carry it up and out of the extract shaft, which usually forms a conspicuous feature on the exterior of the edifice.

Attention should then be drawn to the following points:—

(1) The shaft inlet for air; this is usually of some height, to ensure that the air should be drawn from a pure source.

(2) The screen for filtering the incoming air; this is fixed at the entrance of what is known as the air-inlet trunk.

This screen is composed either of strings of worsted or of coke breeze. A water spray or a supplementary spraying nozzle is provided to play upon the screen in order to cleanse the air and if necessary to moisten it (*see pp.* 631-33).

(3) The fan; this is driven either by a gas engine or an electric motor. The air is thus propelled forward into a main underground trunk which should be well lit, white-washed, scrupulously clean, and of sufficient diameter to allow an adult to pass along its length when necessary.

(4) The warming chamber; here the air is warmed by passing over coils of pipes arranged in batteries and filled either with steam or hot water.

(5) The by-pass doors; these are provided to admit cold, though filtered air, to reduce the temperature in the warming chamber when necessary.

(6) The vertical air-ducts or flues; these lead to each room in the building, and are fitted at their bases with secondary air-warming coils so that the temperature of the air in each room may be regulated independently of that in the others. Valves are also usually fitted in the vertical shaft, with the same object of regulating the quantity and quality of the air which is propelled along them.

The arrangement, size and position of the flues is one of the most important points in such installations, indeed it is that upon which success or failure chiefly depends.

(7) Notice the position of the air inlets and outlets in the different rooms. The former should be on the opposite side of the room from the windows and near the ceiling, unless the room be lit by gas, when the inlet should be at a *lower* level, *i.e.*, below that at which the heated air accumulates. The outlets should be on the same side of the wall

as the inlets, but quite close to the floor level. The area in each case must be in proportion to the cubic capacity of the room and the anticipated number of its occupants.

(8) Place some smouldering cotton waste in the aperture of the air inlet and observe, (*a*) the velocity of the incoming air, (*b*) its direction, (*c*) its course in the room and the extent of its diffusion.

(9) Transfer the smouldering cotton to the aperture of the air outlet and observe whether the smoke is carried away up the extract shaft, or whether it hangs round the opening or is even blown back into the room.

(10) Enquire whether, when the fan is working and the occupants of the room are sitting quietly at rest, any sensation of draught is experienced on the exposed surfaces of the body.

The fact that the air enters under slight pressure results in the continuous forcing out of the air previously within the room, though under certain conditions of atmospheric pressure this pressure is insufficient, and stagnation of the air or even a reverse current is set up. To obviate this risk, it is now usual, in many cases, to install a small fan or a coil of hot pipes at the foot of the extract shaft (or outlet for foul air), in order to exercise an aspirating effect upon the air in those rooms most remote from the propelling fan, and thus to ensure a continual circulation of air throughout the system.

Mention among the disadvantages of the Plenum system of ventilation, none of which are insurmountable:—

(*a*) The sensation of draught experienced when the temperature of the air is raised but no added humidity is supplied (*see page* 633).

The hot, dry air passing over the skin of the face and hands causes a rapid evaporation of moisture from the skin, and gives rise to a sensation mistaken for what is usually called a draught.

(*b*) The propelling force and the degree of pressure produced may be insufficient to secure due circulation of the air in the rooms most remote from the fan.

Two marked advantages attend the employment of some aspirating power in the up-cast shaft to overcome this defect, (i.) the success of the system of air supply is practically ensured, (ii.) the necessity for closed windows ceases to exist, for it is no longer necessary to maintain any increase over the ordinary atmospheric pressure with which the opening of windows would interfere.

(*c*) The great initial cost of such installations as well as their working expenses. The former renders any failure a serious matter, the second leads to the stoppage of the fan during the hours when such buildings are unoccupied, so that foul air and the dust raised by cleansing processes accumulates in the rooms and air shafts. The first is a question of hygiene and economics, for no good work can be performed in overcrowded and ill-ventilated rooms; the second is overcome where windows and doors are freely opened during the intervals when the fan is not at work.

XXVII.—WARMING.

Some sources of heat—physical, mechanical, and chemical. Transmission of heat by conduction, convection, and radiation. Application to the warming of houses. An examination of fuels and of the products of combustion. Effect of heat on metals.

I.—To Illustrate some Sources of Heat.

MATERIALS: *String; nails; sulphuric acid.*

APPARATUS: *Thermometer; glass flask; pipette; test tube; hammer; metal block; Bunsen burner.*

(*A*) *Physical.*

(1) Throw open and stand before a window through which the sun is shining. What is the sensation experienced as the rays of the sun strike upon the person?

(2) For what reason are feelings of chill and fatigue changed to those of warmth and satisfaction when hunger has been satisfied with suitable food?

(3) Note the temperature of a thermometer, breathe on the bulb. Observe the immediate evidence of animal heat afforded by the result.

(*B*) *Mechanical* (Friction).

(1) Take a glass flask, twist a piece of string loosely round the neck, then hold the flask firmly while your companion exerts friction upon the glass by pulling alternately upon the ends of the string for some minutes.

Remove the string and touch the portion of glass which it had covered. The sensation of heat will be well marked.

(2) *Percussion.*—Place a few nails upon a metal block and strike them forcibly and steadily with a hammer. How soon do the nails feel warm instead of cold when touched? What is the source of this rise of temperature?

(*C*) *Chemical.*

(1) *Combustion.*—(*a*) Hold the hand about 15 cms. (6 inches) above a Bunsen burner for a few seconds. Light the gas and repeat the test. What change of sensation is experienced?

(2) *Chemical Combination.*—Fill a small test tube one-third full of cold water. Does the exterior of the tube feel cool or warm to the touch? Add cautiously a few drops of sulphuric acid from a pipette. Again examine the exterior of the tube with the fingers. Has the temperature been raised?

NOTE.—Heat is a condition of matter which can be transferred from one body to another.

Physical sources of heat exist in the sun, in terrestial conditions, in animal heat, in electricity or in molecular activity.

Mechanical sources may be illustrated by friction, by percussion, or by pressure.

Chemical sources of heat are found in combustion and in countless molecular combinations, as for instance in the combination of oxygen and hydrogen when an electrical spark is passed through them, or in the rise of temperature associated with mixing water with sulphuric acid.

In warming houses, or in the production of heat for industrial purposes, combustion is the chief source of heat utilized and applied in various forms.

II.—Transmission of Heat.

MATERIALS: *Wood, metal, earthenware, woollen and cotton objects; wooden, metal, glass, iron, fire-clay or pipe-clay rods; sheet of tin plate; square plate of iron; small sheet of card or paper; plate of glass; small poker or curling tongs; coarse copper wire; fine wire; paraffin wax; corn seeds; small candle; taper; matches; cochineal; litmus.*

APPARATUS: *(Sensitive) thermometers; beakers; c.c. measure; test tubes; large round-bottomed flask; flasks; small thistle funnel; glass tubing; rubber corks; rubber tubing; knife; fish-tail burner; 2 large, bright 7-lb. biscuit tins; measured ruler; tripod; retort stand; Bunsen burner.*

(*A*) *By Conduction.*

(1) Touch a variety of objects (wood, metal, earthenware, woollen or cotton) with your hand, then test the temperature of each object by laying the bulb of a thermometer upon it for some minutes, or by keeping the instrument in close contact with the surface touched. Does the mercury vary in the tube? How do you account for the impressions received when touching the various substances, *viz.*, that some gave a sensation of warmth and others chilled the hand?

(2) Prepare a large beaker or jar of boiling water, plunge three rods, (*a*) wooden, (*b*) metal, (*c*) glass, into the water. Retain the exposed ends until too hot to hold. Is it necessary to release them simultaneously or can the ends (*a*) and (*c*) be held in the hand for any length of time after (*b*) has become painfully hot.

Does this experiment serve to explain (1)? *See also* "CLOTHING," VII. *pages* 532 to 534.

(3) (i.) Take a taper (a) and clamp or otherwise support it on the retort stand.

(ii.) Procure two rods, one of iron (b), one of fire-clay or pipe-clay (c), of the same diameter and length (about $12{\cdot}5 \times 8$ cms. $= 5 \times \frac{1}{3}$ inch).

Support one end of each rod on the tripod stand, and the other ends on the taper, *see Fig.* 117.

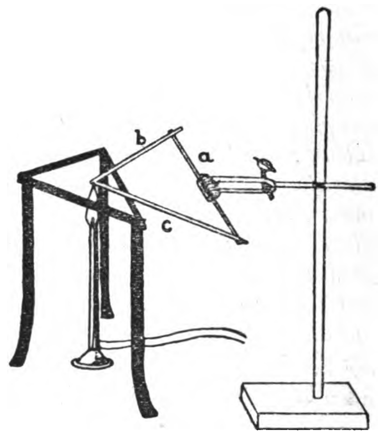

FIG. 117.

Bring the Bunsen flame under the junction of the two rods, and notice which of them drops first from the end of the taper. While watching, test roughly with the hand the relative radiating power of the rods.

(iii.) Cool the rods and lay them across the tripod stand, place a Bunsen burner immediately beneath them. Which of the two glows or becomes red hot first?

(4) Attach a piece of coarse copper wire about 25 cms. (10 ins.) long to the retort stand in such a way that the free end is suspended in the flame of a Bunsen burner.

After a few minutes move the tip of a match slowly along the wire until the match ignites. Notice the distance from

the flame at which this takes place. Bring another match towards the flame from the opposite side moving it through the air; notice the point at which it ignites. Repeat this test, measuring the distance in each case with a foot rule.

What deductions do you draw upon the relative conducting powers of a metal such as copper, or of a mixture of gases such as the atmosphere? Does this explain why copper is often used for kettles and other cooking utensils?

NOTE.—The sensation of heat and cold felt when the skin is in contact with different bodies is materially affected by their conductivity. If their temperature is higher than that of our body they appear warmer than the heat they give up on contact, whereas if their temperature be lower than that of the body their conductivity leads to a rapid loss of heat from the body and an impression of cold is experienced.

(5) Fill a large test tube three-fourths full of water. Hold it near the bottom, incline it horizontally, and heat the portion of the water in the upper part of the tube over a Bunsen flame. Move the tube to and fro or the glass will crack.

When the water boils on the surface, is the tube too hot to be held at its lower end?

Test the poor conducting power of water by introducing a sensitive thermometer to the bottom of the tube directly the water boils; rapidly read the index. Remove the instrument and continue to heat the water. Note the interval before the temperature of the whole contents of the tube has been raised to boiling point by the dual influence of heat conduction and convection.

(*B*) *By Convection.*

(1) (*a*) Take a large flask with a round bottom, fill the body of the flask with water and arrange it on a retort stand over a Bunsen flame.

(*b*) Prepare a small quantity of water in two small beakers (i.) (ii.).

Add to (i.) a few drops of cochineal, and to (ii.) a few drops of litmus solution.

(*c*) Light the Bunsen burner and gently drop a portion of (i.) upon the surface of the water in the flask.

Pass a small thistle funnel into the flask so that the stem reaches almost to the bottom, and drop down it a small quantity of (ii.).

(*d*) Trace the course of the convection currents which result as the heated water, which is immediately over the flame, becomes lighter and rises from the bottom of the flask. Is the downward course of the hot water confined to one current in the flask or are there several ?

Compare "SOME PROPERTIES OF WATER," III. (*A*), *page* 68 ; "THE COOKING OF FOOD," II. (*E*) (*c*), *page* 367.

(2) Fit up as follows the apparatus shown in *Fig.* 118.

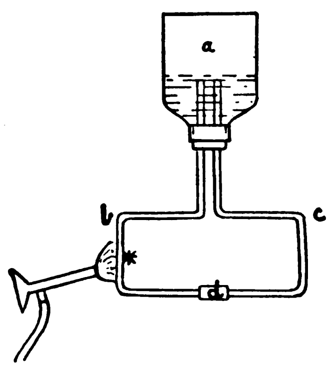

FIG. 118.

Half fill the flask (*a*) with water, pass the ends of the glass tubes (*b*) and (*c*) through a rubber cork, and connect them by a short piece of rubber tubing (*d*). Drop a few particles of litmus on the surface of the water in (*a*) and insert the cork firmly.

Invert the apparatus, grasping (*a*) firmly at the neck ; the water should fill (*b*) and (*c*) and just cover their open ends within (*a*).

Apply a small flame at the place marked * and watch the results. Consider to what use the method of heating by convection is familiarly applied in houses and schools or other large buildings.

(3) (*a*) Heat a pair of curling tongs or a small poker red hot in a Bunsen burner and hold the glowing metal at arm's length between your eyes and the window. The flickering, shimmering appearance of the air just above the red hot mass is caused by the convection currents set in motion by the heated body.

(*b*) Repeat "VENTILATION," V. (*B*) (2) (3), *page* 624. *See also* IV., *Note*, *pp.* 619-22.

Do these experiments illustrate any method of heating by which warm air is diffused through the agency of convection? (*See* "AIR," II. (*D*), *page* 47.)

(*C*) *By Radiation.*

(1) Take a wax taper or a small candle and place it about 10 cms. (4 in.) from, and on a level with, a lighted Bunsen burner.

Observe the effect upon the candle of the heat radiated by the gas flame. Interpose a screen between the candle and the burner in the form of a small sheet of card or plate of glass. Is there any evidence that the heat which caused the candle to melt was radiant and not convected.

(2) Smoke well one half of a sheet of tin-plate by holding it horizontally in a smoky (luminous) flame, whilst keeping the other half of the plate covered with paper. (*Fig.* 119).

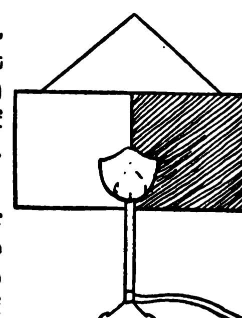

FIG. 119.

Bend a short length of copper wire in the middle and turn up the ends to hook through holes in the tin-plate. Turn the smoky side of the plate downwards and put a

very small piece of paraffin wax in the centre of the back of both smoky and non-smoky halves. Melt the wax on the plate with a warm knife blade, and, while soft, attach a seed of corn to each spot of wax.

Suspend the plate to the clamp of a retort stand and put a luminous fish-tail burner about 2·5 cms. (1 in.) in front of the plate, as nearly as possible midway between the smoked and non-smoked halves of the plate. Notice which seed drops off first.

(3) (i.) Take two large, bright 7-lb. biscuit tins, (*a*) and (*b*). Cut a small hole in the lid of each tin, of just sufficient size to admit the stem of a thermometer, which should be passed through it.

Blacken the whole surface of (*a*) as directed in (2). Measure the cubic capacity of each tin by filling it brimful with water and then pouring it off into a c.c. measure. If the capacity of the two tins does not exactly correspond, measure an equal amount of water into each tin in order that the bulk of their contents shall be identical. The water used for this purpose must be boiling. Cover the tins immediately. Note the temperature recorded in each tin after they have been filled with the boiling water.

Carefully protect from draughts and set aside for half an hour. Then observe whether the temperature has fallen more in one than in the other tin.

(ii.) Empty and cool the tins. When cold, refill them with equal quantities, by measure, of cold water, and replace the covers, through which the thermometers must be passed as in (1). If necessary re-blacken the surface of (*a*).

Take two lengths of fine wire and twist into a cage round each tin, then suspend them side by side from the rings of two retort stands. Arrange two square plates of iron, to measure about 12·5 cms. (5 inches) each way, upon two tripods over Bunsen flames, immediately beneath the tins.

Watch the mercury in the thermometers. In which case is the absorption of heat most rapid?

Do the results of these experiments confirm the following facts:—

(1) That radiant heat does not warm the medium through which it passes;

(2) That dark surfaces absorb more heat than bright or light ones (*see* "CLOTHING," (*V.*), *pp.* 528-9);

(3) That dark surfaces at the same time radiate heat much more rapidly than light or bright ones.

Do these facts also afford reasons for the following old customs:—The use of highly polished metal for tea pots or dish covers, the use of a sooty kettle when it is desired to heat water rapidly over a fire, the white-washing of slate roofs in the summer?

NOTE.—The utmost care must be exercised to protect the tins from outside influences, by the use of card-screens to exclude draughts, etc. In Experiment 3 (i.) the water in (*a*) will cool twice as quickly as that in (*b*), but on account of the great absorbing powers of dark colours the temperature will rise more rapidly in (*a*) than in (*b*) in 3 (ii.).

The amount of radiation from polished metal is about one-fifth of that from any dull surface at the same temperature.

Speaking generally, good radiators of heat such as fire-clay are good absorbers also; good reflectors of heat such as bright metals are bad radiators, while transparent bodies such as the atmosphere are bad radiators.

(4) *Causes which Modify the Intensity of Radiant Heat.*

(*a*) The intensity is proportional to the temperature of the source.

Take a sensitive thermometer, note the temperature, suspend the thermometer from the ring of a retort stand in such a way that its bulb is on a level with the flame of a Bunsen burner, which should be about 20 cms. (8 inches) away. Support a sheet of card behind the retort stand to serve as a screen, and thus prevent the heat rays from passing beyond the thermometer. Regulate the burner for a small flame, light the gas and leave it for 15 minutes.

Note the temperature of the thermometer.

(*b*) Cool the instrument in cold water and allow it to return to the temperature registered before the experiment began. Rearrange all the apparatus as before, but regulate the burner to produce the hottest flame possible. Again note the temperature of the thermometer after 15 minutes and compare with that in (*a*).

(5) *The Intensity is Inversely as the Square of the Distance.*

Take three thermometers, (*a*), (*b*), and (*c*), equally sensitive, and registering the same temperature. Suspend each from a retort stand as in (4) (*a*), and arrange them, each with a card screen behind it, round a Bunsen burner as follows, place

(*a*) at a distance of 30·5 cms. (1 foot),
(*b*) at a distance of 61 cms. (2 feet),
(*c*) at a distance of 91·5 cms. (3 feet).

Note the temperatures recorded after 15 and 30 minutes.

NOTE.—Heat is communicated in one of three ways, (*a*) by direct contact or conduction, *i.e.*, when it passes from particle to particle through a body; (*b*) by carrying or conveyance, technically termed convection, which has been defined as the distribution of heat in a fluid body by a motion of its own particles; (*c*) by radiation, when heat passes from one point to another in straight lines at a great speed without heating the medium through which it passes.

Bodies conduct heat with different degrees of facility. Dense bodies such as metals conduct heat rapidly, silver and copper being the best known conductors. Glass, wood and wool are poor conductors, gases rank lowest in this respect, though the conducting power of liquids is very small as is demonstrated in II. (*A*) (5). A perfect non-conductor would entirely inhibit the transmission of heat, but no such substance is known to exist.

Liquids and gases are heated by convection, whereas solids are heated either by conduction or radiation or by a combination of these two methods of heat transmission.

Air would be a good heat insulator were it not for its fluid mobility; cotton or wool is very efficient for preventing the escape of heat from hot bodies by interfering with this mobility. Wood, glass, asbestos, india-rubber, felt, paper, etc., are also very useful for the purpose. For instance,

the loss of heat from steam boilers is now generally considerably diminished by coating them with a thick layer of some badly conducting composition such as asbestos or felt, while chimneys and flues should be massed in the centre of a building to reduce the loss of heat by radiation, and not dispersed at different points on the exposed walls.

Heat for the purposes of warming is mainly due to combustion, that is, to the chemical action which occurs when the oxygen of the air combines with fuels such as wood, coal, oil, or coal gas, of which there are many kinds—solid, liquid or gaseous.

The process of oxidation is attended with the evolution of a large quantity of heat; carbonic acid gas and water are the principal products of combustion (*see* "*Air*," IV. (*A*) (1), (*a*), (*b*), (*D*) (1), *pp*. 53-57).

All heating appliances depend upon the transference of heat from some source to the parts of the room or building which it is desired to warm. The transfer is effected in one of these three ways—(1) by the slow process of conduction; (2) by the quicker process of convection; or (3) by the rapid process of radiation.

The domestic fireplace illustrates (2) and (3), while all three forms are at work in the case of hot-water pipes, for the heat is conducted through the iron pipes, which in their turn warm the room both by radiation and convection (*see Experiment* II. (*B*) (2)).

As radiant heat is unquestionably the most healthy for domestic purposes, because it promotes ventilation and yet adds no impurities to the air of the room, much trouble has been devoted of recent years to the improvement of open fireplaces in order to secure the maximum heat radiation combined with the minimum consumption of coal (*Figs*. 113 and 120, *pp*. 621, 650).

III.—Applications to the Warming of Houses.

MATERIALS: *Open fire-place; gas stove; litmus.*

APPARATUS: *Large aspirator; T-shaped glass tube; glass tubing; rubber corks; rubber tubing; Bunsen burner.*

(*A*) Examine an open fire-place, its structure and the materials of which it is composed.

Is it so arranged that the waste of heat is as small as is consistent with the adequate efficiency of the chimney for the purposes of ventilation.

Remember that while it is the healthiest method of heating a room it possesses serious disadvantages in the loss of much heat, the cost of fuel, and its feebleness at any distance (the effect lessens as the square of the distance).

To what extent does it comply with the correct principles of fire-place construction worked out by Mr. Pridgin Teale, F.R.S. (*Fig.* 120), (*also* "VENTILATION," IV., NOTE, *Figs.* 113, 114, *pp.* 621-2).

FIG. 120.

(1) As little iron as possible (II. (*A*) (3)).

(2) The back and sides of brick or fire-brick (II. (*A*) (3)).

(3) The fire-brick back should lean over the fire at an angle of 70°, not incline away from it.

(4) The bottom of the fire or grating should be deep from before backwards (not less than 22·5 cms. (9 inches) for a small room nor more than 27·5 cms. (11 inches) for a large one).

(5) The sides or "coving" of the fireplace should be vertical, but inclined to one another as the sides of an equilateral triangle, the apex of which should be behind the fireplace and the base in a line with the front.

(6) The shape of the grate should be based upon a square described within an equilateral triangle, the size to vary in constant proportion to the size of the square.

(7) The slits in the grating or grid should be very narrow, the front bars should be vertical, that ashes may not lodge, narrow (6·2 mm. = $\frac{1}{4}$ inch) not to obstruct heat, and close together (18·6 mm. = $\frac{3}{4}$ inch) to prevent coal and cinders from falling on the hearth.

(8) The chamber under the fire should be closed by a shield or economizer, which is usually made of sheet iron. This stands on the hearth and rises as high as the lowest bar of the grate, against which it should fit accurately, so as to shut in the space or chamber under the fire.

(*B*) Study these principles as exemplified in *Figs.* 113, 114, 120, *pp.* 621-2 and 650.

Notice also (1) the glazed tiles and fire-brick construction which increase the heat and lessen labour; (2) the ash-pan by which the ashes can be withdrawn from beneath the sunk fire and emptied without dust.

In consequence of the complete combustion which characterises a well constructed grate, the ashes should not amount daily to more than about 85 to 113 grams (3 to 4 oz.).

NOTE.—(*a*) The only parts of a fireplace necessarily made of iron are the grid on which the coal rests and the bars in front.

(*b*) Brick does not conduct well, but accumulates and retains heat, whereas iron conducts rapidly, chills the fuel, and does not store heat like brick. In badly constructed grates at least 40% of the heat is allowed to escape up the chimney, while a third of this amount may also be lost by conduction.

(*c*) The lean-over back is in a favourable position for absorbing heat from the rising flame. The heat radiates from this back and raises to combustion point the temperature of gases, which would otherwise pass up the chimney and be lost, thus largely minimizing smoke.

The lean-over should commence about 30 cms. (1 ft.) from the hearth. The temperature attained by the fire-brick is such that, when the products of combustion come in contact with it, plus the current of air which passes over the fire and up the chimney, they are almost wholly consumed.

(*d*) This is a corollary to (*c*). The lean-over back is for obvious reasons impossible if the grid be shallow.

(*e*) If the "covings" are parallel to each other they radiate most of their heat from one to the other and not into the room. The angle of 60° was determined by the fact that, as a heated brick throws off the greatest amount of radiant heat at a right angle to its surface, the "covings" should be at such an inclination to each other that the perpendicular line from the inner margin of one "coving" should just miss the outer margin of the opposite "coving."

(*f*) The slow and efficient combustion of coal in house fires depends upon two conditions in combination, which are observed in the form of fire-place under observation, *viz.*, that no current of air should pass through the grate at the bottom of the fire, and that the space or chamber under the fire should be kept hot.

(*C*) Examine a gas-stove, its structure, parts and fittings. What form of heat is employed to warm the room where a gas-stove is fitted. How far does it conform to the following requirements of an ideal method of heating, *viz.*:

(1) The maintenance of a regular temperature without causing draughts or adding impurities to the atmosphere.

(2) That the source of heat should be cleanly and economical in labour and in cost of fuel.

(3) That it should promote ventilation.

For what reason is the stove lined with fire-clay, and why is this material, or asbestos, employed for "fuel."

Notice the arrangement of the fire-clay lumps. These are so placed that the apertures in the lumps are well over the Bunsen burners; they are raised from the burners to prevent the flame from impinging too soon on a cold surface.

NOTE.—A properly constructed gas fire maintains a far more equable temperature than a coal fire and can be more easily regulated to meet the exact needs of the moment, but it *must* be provided with a flue of sufficient size to carry away the products of combustion. When this is provided, it is the opinion of experts that a gas fire is as satisfactory as a coal fire from a hygienic point of view; it does not vitiate the air of a room, nor does it produce any abnormal drying effect, as is popularly supposed. A gas-stove with a good flue will carry off from 2,000 to 4,000 cubic feet of air per hour, thus serving as a powerful exhaust ventilator, while there is an entire absence of dust or smoke, and a great economy of labour. Flueless gas-stoves must be emphatically condemned.

All the joints of flues and gas-stoves must be perfectly air-tight to avoid the grave risk to health and life associated with any leakage of carbon monoxide gas (*page* 657). This highly poisonous gas also traverses the walls of a stove if they become red hot.

Cast-iron stoves are peculiarly liable to become overheated because the metal is so good a conductor, they should therefore never be used unless lined with fire-clay, a first-rate non-conductor of heat.

(*D*) Fit up a model as figured to illustrate the principles of heating by a Low-Pressure Hot-Water System.

(1) Take a large aspirator (A) and fit both orifices with rubber corks, through which pass short lengths of glass tubing (C) and (D).

Connect (C) with a T-shaped piece of glass tube (B), and (D) with (E), by means of short lengths of rubber tubing. (A) represents a closed cylinder fitted with a flow pipe at the top (C) and a return pipe at the side (E). (B) illustrates the expansion pipe fixed from the highest point of the circulation.

(2) Fill the whole apparatus with water except the long limb of (B), but first place a few particles of litmus at the bottom of (A).

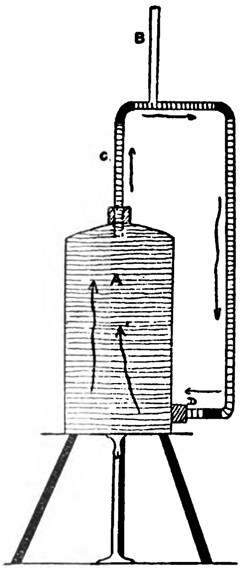

FIG. 121.

Arrange the whole on a sand-bath over a Bunsen burner and light the gas, then watch the results on the water as the temperature is raised. The heating process must be carried on very cautiously or the aspirator will break.

The water expands as heat is applied to the bottom of the vessel, it becomes lighter ("WATER," III. (*A*), *page* 63), and is displaced by colder, heavier water from the bottom of the "return" pipe (D), thus causing it to ascend towards the "flow pipe" (C).

Continue to heat the aspirator; observe the rise of water in (B) which thus acts as a safety value.

NOTE.—The efficiency of a hot-water system depends upon the circulation of water in the pipes, which continues so long as the heat is kept up. The motive power is the difference between the weight of the column of comparatively cold water which descends in (D), and of the hot-water column which is consequently forced upwards to the flow-pipe (C). In a properly constructed hot-water apparatus boiler, ebullition only takes place when the circulation is impeded, its construction should be designed to promote very rapid circulation.

Pupils should be shown all the details of a system of heating by hot water and by steam in order that their relative values may be appreciated. Particular attention should be

directed to any means taken to make good the absence of ventilation associated with these methods, and of the measure of success with which they are attended.

The *advantages* of these systems in comparison with heating by open grates or stoves may be summarized as follows:—

(1) There is only one central fire to be attended to, at a place close to the coal store. This saves dirt, labour and time.

(2) The temperature of each room can be regulated to the desired degree, though ventilation is not, unfortunately, as easily effected as by open fires.

(3) The radiating surfaces can be placed in the best possible positions for giving the desired results of warmth and circulation of the air, but they do not provide for the introduction of fresh air.

(4) Equable warmth over a whole apartment can be obtained without difficulty.

(5) There is no danger to children if left alone in a room. If the radiating surfaces are kept at a relatively low temperature, the passage of the incoming air over them will not deteriorate it, as may be the case where the air is passed over highly heated surfaces in contact with gases produced by burning fuel.

Two serious objections to this method of heating are the increased expense and care which are entailed if ventilation is to be promoted, and the unpleasant and unwholesome results which follow any overheating of the metal pipes (*page* 653).

"Steam" heating possesses the advantage that the high temperature of the coils gives out radiant heat, in the same way as, though in less degree than, in the case of an open fire, and the heat can be got up and let down much more rapidly than when generated by hot water.

IV.—An Examination of Fuels.

Materials: *Pieces of wood, coal, coke, candle and mutton fat; bicycle oil; methylated spirit; kerosene; wood charcoal; powdered copper oxide; thin wire; lime-water.*

Apparatus: *Hard glass test tube; glass tubing; beaker; gas-jar; glass plate; rubber corks; deflagrating spoon; Bunsen burner.*

(*A*) *To prove the presence of Carbon in Fuels.*

(1) Take 3 or 4 grams ($\frac{1}{2}$ a teaspoonful) of wood charcoal and mix it thoroughly with twenty times the quantity by weight of dry, powdered copper oxide. Put the mixture into a large, dry test tube (*a*), and close the mouth with a rubber cork through which is passed a piece of glass tubing bent twice at right angles (*b*). This tube should project only just below the end of the cork in the test tube. Half fill a small beaker with lime water (*c*), and introduce the long limb of (*b*) well below the surface of (*c*).

Hold the test tube by the cork in a slightly inclined position, and wave the flame of a Bunsen burner to and fro beneath the portion of it which contains the mixture. Observe the gradual formation of a film of chalk in (*c*).

Continue the heating process for some time, then remove (*b*) from (*c*), extinguish the gas and examine the appearance of the tube. What further proof is afforded that the carbon mixed with the copper oxide has combined with the oxygen and has passed off as carbon dioxide gas?

(2) Repeat (1) but substitute powdered coal for wood charcoal.

NOTE.—The inner surface of the tube which was exposed to the heat will be coated with a dull, red substance, metallic copper.

(*B*) Demonstrate the products of combustion as follows:—

(1) Take a small piece of dry wood, twist round it a piece of the wire, hold the wood in a Bunsen flame until it ignites, then lower it into a cold gas jar.

Withdraw it from the jar when it ceases to burn; is there any evidence that moisture is a product of combustion?

Pour a few drops of lime water into the jar, cover it with a greased plate and shake it well.

Notice the abundant evidence afforded of carbon dioxide gas.

(2) Repeat this experiment but substitute for the wood—

(*a*) A small piece of coal,
(*b*) A small piece of coke,
(*c*) A piece of candle,
(*d*) A piece of mutton fat,
(*e*) A few drops of kerosene
(*f*) A few drops of bicycle oil
(*g*) A few drops of methylated spirit

} contained in the cup of a deflagrating spoon.

Are similar results observed in each case ?

NOTE.—The combustible elements in these fuels are carbon and hydrogen, though most of them contain some oxygen in addition, the sole product of burning carbon is carbon dioxide gas, but if insufficient air is supplied the combustion is incomplete and the poisonous gas, carbon monoxide, is also formed. If a blue flame is seen, it shows that the carbon monoxide is being burnt, and so, presumably, is not escaping.

Nothing but water in the form of steam is the product of the combustion of hydrogen, though, of course, combustibles are rarely if ever composed of a combination of pure carbon and pure hydrogen, so that certain impurities are usually present, of which the only one of importance is sulphur.

V.—The Effect of Heat on Metals.

MATERIALS : *Copper tape ; blocks of wood ; tacks ; thin card ; large pin ; dust.*

APPARATUS : *Thermometer ; porcelain bowl ; small thin plate of iron ; hammer ; sharp knife ; measured ruler ; retort stand ; Bunsen burner.*

(*A*) *Expansion.*

Take a length of copper tape (*a*) (such as is used for lightning conductors), about 50 cms. (20 inches) long and support its two ends on blocks of wood. Fix the strip at one end by making a stop with two tin tacks.

Cut a wedge-shaped piece of thin card or thick paper (*b*), pass a large pin (*c*) through its base and lay the pin across the block under the free end of (*a*). Place a Bunsen burner under the centre of (*a*), light the gas and watch (*b*).

As the copper becomes heated it will expand, increasing actually in both length and breadth. The movements of (*b*) are the result of the rotation of (*c*) under the pressure exercised by (*a*) as this elongation takes place.

NOTE.—Allowance should be always made for the expansion of metals when heated, otherwise joints in hot-water or steam-heating installations are subjected to too severe a strain and leakages of gases or of water are the result. Various methods are employed to estimate how much a body (solid, liquid or gaseous) expands when heated through any particular range of temperature. When this expansion is expressed as a fraction of length or of volume at some one temperature it is called the co-efficient of expansion, not only for the particular portion of a substance which may be the subject of the experiment but for the same substance under other conditions. The expansion of an iron rod over 100° C. (212° F.) is very small. It is stated that a rod 7·61 metres (25 feet) long would only elongate about 1 cm. ($\frac{3}{8}$ in.) when heated through this range of temperature.

Steam pipes are left loose jointed, and the bars at the top of a gas stove are left loose, to allow the metal to expand or contract with changes of temperature, without injury to the apparatus.

(*B*) *Decomposition or Charring of Dust.*

(1) Collect some dust from exposed surfaces in the room and sprinkle it thickly over a small thin plate of iron (about 10 × 10 cms., 4 × 4 inches).

(2) Arrange a porcelain bowl on a retort stand over a Bunsen burner, half fill it with boiling water, cover it with the iron plate and light the gas.

(3) Suspend a thermometer from a second ring on the retort stand so that its tip just touches the iron plate. Watch the temperature as it rises to 70° C. (158° F.), 75° C. (167° F.), 80° C. (176° F.).

Sniff the odour which arises from the charred dust, is this noticeably affected by the rise of temperature?

(4) Extinguish the gas, cool the plate, and then repeat the experiment, but slightly damp the dust before proceeding to raise its temperature.

Does this perceptibly affect the results?

NOTE.—Professor Nussbaum has carried out a series of observations, extending over several years, into the character of the dust deposited on the pipes used for the distribution of hot water or steam, and into the products of decomposition of such dust. He found that when the temperature reaches 70° C. (158° F.) this dust begins to decompose, and that between 75° C. (167° F.) and 80° C. (176° F.) such action goes forward with great rapidity. The smell complained of resembled that of a stable, and is due to the chemical action of the particles of organic matter which form a large proportion of the dust deposited in dwellings and public buildings. In the course of certain experiments ammonia was freely evolved from the dust when the temperature rose to 80° C. (176° F.). It had been previously observed that the smell was always worse when the heating apparatus was used after a long interval of rest; when the cause had been discovered and the dust was first carefully cleared away the smell partly disappeared, though some smell, due to floating dust in the atmosphere, remained.

When the surface of the pipes is damp, decomposition takes place at lower temperatures than when the dust is perfectly dry.

XXVIII.—LIGHTING. NATURAL AND ARTIFICIAL.

Elementary study of vision and optics. Comparative intensity of reflected light. Passage of light through different media. Principles of combustion as they affect illumination and some sources of artificial light. The size and position of windows. Relationship of height of buildings to width of streets.

I.—Elementary Study of Vision and Optics.

Repeat "THE EYE," XIII., I. (*A*), V. (*A*) (*B*) (*F*) (*G*), and "THE CARE OF THE PERSON," IV., (*A*) "The Eyes," *pages* 483-86.

NOTE.—(1) The provision made for the protection of the eyes.
(2) The mechanism of visual accommodation.
(3) The retention of vision.
(4) The phenomenon of irradiation.
(5) The effect of the refraction of light upon the visual horizon.
(6) The decomposition of white light and the phenomena of the spectrum.

(7) The cause of shadows.

(8) The importance of position relative to the source of light in order to assist vision, as well as the detrimental results to general health and the possible permanent injury to the eyes which are associated with defective light and eye-strain.

II.—Intensity of Reflected Light.

MATERIALS: *Flat mirror; sheets of cream-coloured and dark blue paper; small pieces of bright metal, white satin, black crêpe; flat pieces of dark unpolished and light polished wood; cardboard tube; light dust.*

(*A*) (1) Arrange the following series of articles horizontally upon a table:—

(*a*) A flat mirror.

(*b*) A piece of bright metal, such as the lid of a biscuit tin.

(*c*) A sheet of cream-coloured paper.

(*d*) A sheet of dark blue paper.

(*e*) A piece of white satin.

(*f*) A piece of black crêpe.

(*g*) A flat piece of dark, unpolished wood.

(*h*) A similar piece of light, polished wood.

(2) Darken the room, but leave a small aperture through which a beam of light can enter from the window.

Take a tube of cardboard, and manipulate it in such fashion as to focus the beam of light successively upon each of the articles.

If you accept the fact that light is beneficial to health, contributes to cleanliness and is indispensable to the eyesight, what suggestions would you make upon the decoration and furnishing of rooms, as a result of your observations upon the reflecting powers of these different substances.

(*B*) Sprinkle some light dust upon the surfaces of (*a*) and (*b*), again direct the beam of light to fall successively upon them. Do the results vary from those noted in (*A*) (2)?

NOTE.—Of the light which falls on a transparent body a large proportion is transmitted with regularity; the reflecting surface, *e.g.*, of a mirror, is not visible, but only the image of the sun or other source from which the light proceeds (*See* (*A*).)

If the reflecting power of perfectly smooth, highly polished, reflecting surfaces be diminished as in (*B*), then the image of the reflecting surface becomes visible; that is, in experiment (*B*) the mirror and tin plate will be visible from all parts of the darkened room, while in (*A*) their presence will be only indicated by the light they reflect. The intensity of reflected light is always less than that of the incident light, but it increases with the obliquity of the incident ray.

Ganot states that "with perpendicular incidence the light reflected from a metal mirror is $\frac{3}{5}$ of the incident light, $\frac{3}{4}$ from mercury, $\frac{1}{25}$ from glass, and $\frac{1}{50}$ from water. It also varies with the nature of the medium which the ray is traversing before and after reflection. Polished glass immersed in water loses a great part of its reflecting power."

As a general rule, dark, dull, rough surfaces absorb light, whereas light colours and smooth, polished surfaces reflect it.

The illumination of a room depends very largely not only upon the aspect of its windows, north, south, east or west, but upon the colour and texture of its floor, walls and furniture.

Pupils should be exercised in the selection of schemes of decoration suitable for rooms of various aspects, and should understand the great advantage of employing colours and materials which reflect light rather than those which absorb it, especially in a climate where there is often a great deficiency of bright sunshine and a prevalence of cloud and fog.

The colour selected for walls must not only absorb the least amount of light but should not fatigue the eyes. Yellows and buffs, for instance, fulfil the first condition but not the second, for investigations show that yellow fatigues the eyes to a marked extent, whereas a light green, which comes next to yellow in the curve of the degree of illumination of the solar spectrum, by its restfulness fulfils both requirements.

A combination of Antwerp blue and raw sienna, with white as a base, will give a soft, greenish-gray colour, most suitable for wall surfaces, or, when a darker tint is required,

these colours can be combined to give a rich yet still restful colour, well suited for the woodwork of sunny rooms. It is stated that the contrast between the light reflected from green and that of ordinary diffused daylight is less for the eye than is the contrast between light reflected from any other colour and diffused daylight.

III.—How to Discriminate between a Tint, a Shade, and a Broken Colour.

MATERIALS: *Maxwell or "A.L." Colour Top with discs.*

Demonstrate, by suitable arrangement of the discs on a Maxwell or "A.L." Colour Top.

(1) *A tint, i.e.*, combine any coloured disc with a white one and rotate the top rapidly.

Repeat, varying the proportion displayed of the white disc, and notice the gradation in depth of tint obtained.

(2) *A shade*, repeat (1) but replace the white disc by a black one.

(3) *A broken colour*, repeat (1) but combine a coloured disc with both the black and the white discs, varying the proportions exposed of the two discs; compare the effects obtained with those in (1) and (2).

IV.—Passage of Light through Different Media.

MATERIALS: *Cardboard box; page of well-printed matter; pieces of ordinary, figured, and ground glass; pieces of transparent and figured Swiss muslin; sprig of evergreen.*

APPARATUS: *Measured ruler.*

(*A*) Take a cardboard box to measure about 27·5 × 11·25 × 8·5 cms. (11 × 4½ × 3½ ins.), an ordinary card boot-box answers the purpose well. Remove the lid, and paste a page of well printed matter on the inside surface of one end of the box; cut away the opposite end and replace the lid.

Cut a narrow slit 10 cms. (4 ins.) in length horizontally across the lid, close to that end of the box from which the card has been cut away.

Procure three specimens of glass to measure $10 \times 8{\cdot}5$ cms. ($4 \times 3\frac{1}{2}$ ins.), *viz.*:—

(1) Ordinary glass, such as is used to glaze windows.
(2) Figured glass.
(3) Ground glass.

Slip (1) through the slit in the cover, stand with the back to a good light, raise the box to a level with the eyes and read the printed matter pasted at the further end.

Remove (1), substitute (2) and repeat the test. Can the print be read with equal ease?

Remove (2) and introduce (3) in its place, and repeat the test. What do the results teach as to the effect of different kinds of glass upon the passage of light into a room?

(*B*) Replace (1) as in (*A*), but before slipping it into position cover the inner surface of the glass with a piece of transparent muslin.

Does this materially affect the ease with which the printed matter can be read?

Withdraw (1), remove the muslin, and substitute a piece of figured, Swiss muslin curtain, such as is in common use for window draperies; then replace (1) in the box.

Is the printed matter still legible?

Now hold a sprig of evergreen between your eyes and the pane of glass. To what extent is the admission of light to the box further curtailed?

NOTE.—All authorities are agreed that clear glass should be used for windows. Ground glass, figured glass, and rough plate glass distort the rays of light and cause irregular and dazzling streaks of light (an objection which also applies to venetian blinds). Galton calculated that the loss of light through windows as affected by the quality of the glass amounts in:—

Polished British Plate Glass $\frac{1}{4}$ in. thick	to 13%
36 oz. sheet glass	to 22%
Cast plate glass $\frac{1}{4}$ in. thick	to 30%
Rolled plate glass, 4 corrugations to an inch	to 53%
While in ground glass the amount of light intercepted amounts	to 70%

On the other hand, where the expanse of sky is largely curtailed by the proximity of buildings, effective lighting can be increased as much as fifty per cent. if the upper third or even half of the windows be glazed with factory ribbed glass, plain on one side, having 8 ribs to the centimetre (20 ribs to the inch), in true concave and convex curves. (*Fig.* 122) (*a*). The ribs should run horizontally unless a narrow vertical opening expose a low sky-line between the buildings, when the ribs should be set vertically.

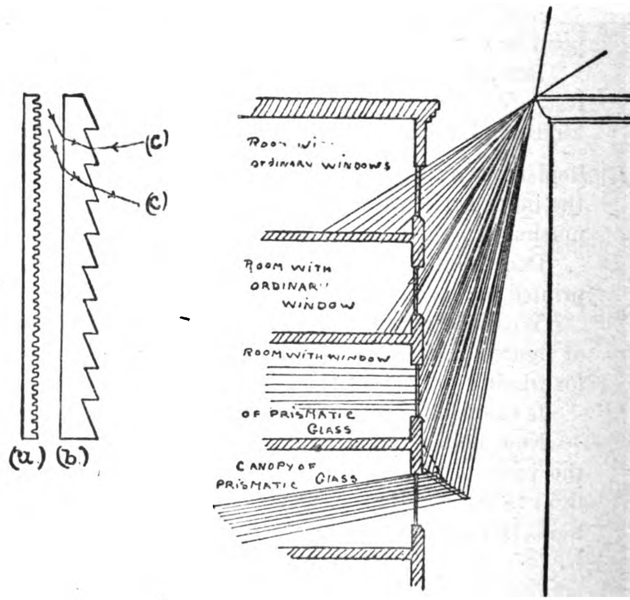

FIG. 122.—(*a*) corrugated, (*b*) prism glass.

The bright, gleaming lines of ribbed glass constitute an objection to its use in the opinion of some authorities, which is non-existent in the case of what is known as prism glass. This consists of thick, small panes with raised prisms on one side, the angles of which vary in different panes so that they gather light from any expanse of sky from 45° of exposure to the zenith and refract it to any part of the room which may be desired. (*Fig.* 122) (*b*)). Such glass is invaluable in large towns, but its cost and the extra labour

involved in keeping it clean militate against its general employment. Much draping of windows should be discouraged in the interests of eyesight and of cleanliness. Where for any reason it is necessary to exclude the direct rays of the sun from a room while in occupation, dark, opaque blinds or curtains must be avoided, or semi-darkness will impose an undue visual strain. In case cream or ecru coloured materials prove insufficient for the purpose, a light sage green or holland colour meet all requirements, they both temper and diffuse, but do not exclude, the light.

In any case of doubt the now accepted very simple test for adequate illumination of a room should be employed. Select a passage printed in pearl type, as for instance the following. If this can be read by the normal eye in any part of the room at a distance of 35 cms. (14 ins.) from the eye, even when the blinds are drawn, the light is satisfactory.

"In the still room there's no sound to disquiet;
Only the clock ticking even and low;
Only the bird in his cage hanging by it,
Chirping a note as he hops to and fro.
Out in the sunlight the woodbine is stirring,
Filling the air with its fragrance so sweet,
On the low window-seat pussy sits purring,
Washing her face with her little white feet."

"Moral Songs."—*Mrs. Alexander.*

Many rooms are darkened by overgrown shrubs or creepers, overhanging eaves, verandahs or balconies. The former should be cut back at intervals, the latter should have the surfaces presented to the windows whitewashed at sufficiently frequent intervals in order to make the best of unsatisfactory conditions.

V.—Principles of Combustion as they affect Illumination.

MATERIALS: *Candle; common salt; piece of white card; lamp wick; filter paper; taper; sand; matches; lime-water; lamp oil.*

APPARATUS: *Small gas-jar; 250 c.c. flask; c.c. measure; test tube; glass tube; glass plates; beehive cell; pneumatic trough; thermometer; oil lamp; tin cup; specimens of argand, batswing, fish tail and incandescent gas burners; retort stand; tripod; knife; sand-bath; Bunsen burner.*

(*A*) (1) Light a candle and examine the flame. Observe:—

(*a*) The almost invisible outer zone of the flame. The inner part of this zone is coloured a faint blue at the bottom, but it can only be traced right round the top with some difficulty. In order to trace it with certainty, sprinkle a few grains of finely-powdered common salt over the flame. The golden-yellow fringe which flashes out is characteristic of sodium chloride (*page* 177).

(*b*) The bright yellow luminous zone.

(*c*) A dark, inner zone, close to the wick.

(*d*) The little pool of melted wax at the base of the wick.

(2) Arrange the collar of the Bunsen burner to allow of a luminous flame; light the gas and compare the parts of the flame with (1), (*a*), (*b*), and (*c*). They will be found to be identical.

(3) Blow out the candle and bring a lighted match slowly down into the stream of whitish smoke which rises from the extinguished wick.

Compare the little puff which precedes the relighting of the candle with the same kind of sound which occurs when gas is lit at a burner. It is caused by the combination of the heated gas with the oxygen in the air.

(4) Show, as follows, that the candle smoke is really gas, and that this gas is made by heating a combustible material such as wax, oil, coal or gases.

Shred several strips from the candle used in (1), collect them in a small test tube and heat the tube in a Bunsen flame.

As the wax boils, a smoky vapour will pour from the mouth of the tube. Immediately apply a lighted match, when a bright flame of burning gas will result.

What is necessary to the ignition of this gas? (*cf.* "Air," II., (*G*) (2), *page* 49).

(5) Examine the characteristics of the three zones in a flame.

(*a*) Hold a wooden match steadily across the middle of the candle flame just above the wick. Is the portion exposed to the flame charred equally along its whole length, or would its appearance when removed from the flame suggest that the temperature of the dark, inner zone is not so high as that of those which surround it?

Test the accuracy of this observation by holding a small piece of white card in the same position as the match and note its appearance on the portion exposed to the flame.

Does the charred ring confirm the fact that the outside of the flame is hotter than the inside?

(*b*) Take a short length of glass tube and hold it steadily in a horizontal position just above the flame for a few minutes until two well-defined black rings have formed on the tube. Remove it, allow it to cool, and examine the character of the black deposit (soot or carbon). Show that it is carbon and a product of incomplete combustion by holding the portion of glass tube upon which one of the dark rings is well marked very carefully and steadily *just* above the top of the candle flame. Notice the complete combustion of the carbon which takes place when the glass becomes very hot.

(*c*) Demonstrate as follows that the candle gas in the cool, inner zone does not burn because it has no air ("Air," II. (*G*), *page* 49), but that it becomes inflammable when conducted into contact with air.

Take a glass tube about 15 cms. (6 inches) long. Clamp it to a retort stand, so that one end is suspended in the flame of a candle just above the wick.

When yellowish fumes pour out from the other end of the tube repeat (4).

The flame will be small and flickering but sufficient to afford the desired proof.

Shift the relative positions of the tube and flame so that the former comes in contact with the luminous zone only. What is the result?

Repeat this experiment with the Bunsen burner, arranging it to produce a luminous flame by closing the holes in the collar.

Do the results confirm the implied fact that gas requires air to become inflammable, whether its source be wax or coal?

(*d*) Demonstrate, by the products obtained, *viz.* (carbon dioxide and water) that complete combustion takes place in the invisible outer zone of a flame.

Hold a small, cold gas-jar over the flames (1) of the candle, (2) of the Bunsen burner.

Notice the deposit of moisture upon the cool surface.

Slip a glass plate over the mouth of the jar, invert it and introduce a few drops of lime-water. Compare the results in both cases with "AIR," IV. (*A*) (1), *page* 53, (*C*) (1), *page* 57.

NOTE.—This production of heat (*i.e.*, combustion) is measurable whatever its rapidity, and is expressed in calories (*page* 78). The heat which accompanies the combustion to carbon dioxide of 1 gram of pure carbon amounts to 8,080 small calories.

The point of ignition (or temperature of any combustible body at which it produces flame) varies widely. That of phosphorus is very low, hence its common use for lucifer matches.

If the temperature of a flame is reduced below the point of ignition of the vapours consumed in it, it is extinguished.

The experiments show that as there is no combustion in the central zone of a flame where hydrocarbons are vaporized, a flame is therefore hollow; also that light is mainly due to the particles of carbon present becoming white hot and luminous or incandescent. These particles are deposited as soot, when cooled upon the surface, for example, of the glass rod or card.

The complete combustion in the outer zone is due to the admixture of the vapours from the hydrocarbons with an excess of air, which results in the production of great heat but of little light.

That an excess of air increases the temperature but diminishes the light given by a flame is easily demonstrated with a Bunsen burner. When the moveable collar is arranged to cover the one or two holes at the base of the small fixed tube the flame of the lighted gas is luminous; rotate the collar and uncover the holes, the flame becomes at once blue and, in strong sunlight, invisible.

The only important difference between the flame of a candle and that of a gas burner is that, in the latter, the inflammable matter is in a gaseous form throughout, whereas, in the former, a solid substance has to be vaporized before it is rendered combustible.

This characteristic of flame is turned to account in the production of heat in gas stoves, where attention is drawn to any interference with the necessary supply of air by the yellow colour of the flame.

A candle or lamp will smoke not only when the supply of air is insufficient but when the gas from the candle or oil is supplied so quickly (for instance, when the wick is too long), that part of the carbon never gets hot enough to burn. Such smoke is not only objectionable, but a waste, representing as it does unconsumed carbon. Were the conditions of combustion perfect, the unburned carbon, usually called smoke, would be all reduced to carbon dioxide gas.

All illuminants, with the exception of the incandescent electrical lamp, change the character of the air by—(1) the consumption of oxygen; (2) the production of carbonic acid gas and steam; (3) the production of small quantities of other compounds.

Artificial light should be sufficient in quantity, steady, uniform, not too heating, nor casting shadows upon the work or causing a glare to the eyes. Ventilation should be so controlled as to prevent deterioration of the atmosphere, and the sources of light should be so arranged that work can be carried on by healthy persons to a practically unlimited extent.

With the exception of electric light all sources of artificial light are too poor in blue or violet rays: the necessary consequence being that the light is of a reddish-yellow or orange colour compared with sunlight, and disguises more or less the natural colours of all the objects which it displays. Its illuminating power, too, is feeble when compared with

even weak, diffused daylight. This appears to be partly the lack of defining power consequent upon falseness of colour, and partly an absolute inadequacy of all the elements of the spectrum.

All artificial light comes from a single, definite local source or direction, instead of being universally diffused as is solar light, consequently it throws heavy shadows.

All artificial light, also, is more or less flickering and unsteady, varying in intensity from minute to minute.

(*e*) Examine several specimens of gas-burners; fish-tail, bats-wing, argand, etc., and notice in what way they are designed to—

(i.) Produce good luminous flames by a due admixture with air.

(ii.) Permit of easy regulation of the size of the flames according to the pressure of gas in the pipes.

(iii.) Ensure that no leakage of gas shall take place from burners or joints.

(*f*) Study the principle upon which incandescent gas burners are designed.

Observe that the specimen supplied is a modification of a Bunsen burner and gives a non-luminous flame; notice that the outer zone of the flame comes in contact with a *mantle*, which performs the part played by the solid particles of incandescent carbon in the luminous zone of a candle. Light of intense brilliance combined with complete combustion of the gas is the result.

NOTE.—The contribution they make to the air pollution in ill-ventilated rooms constitutes a serious objection to the use of the old types of gas burners, in addition to their extravagant consumption of gas. The same amount of light is now obtained by burners in which the combustion is practically perfect and the consumption of gas but $\frac{1}{8}$ or $\frac{1}{10}$ of that under old methods.

The Welsbach mantle is composed of a delicate network of rare earth, thoria, with a 1 or 2 per cent. admixture of ceria. The function of the gas is to generate heat and that of the mantle to transform the non-luminous heat energy into luminous light radiation.

(*B*) *The Cause of Domestic Gas Explosions.*

(1) Fill a 250 c.c. flask brimful of water, cover its mouth with a glass plate and rapidly invert it over a beehive cell previously submerged in a pneumatic trough, in which the depth of the water is sufficient to extend some centimetres above the beehive cell.

Disconnect a Bunsen burner from the rubber tube by which it is attached to the gas pipe, introduce the free end of the tube under the mouth of the inverted flask, turn on the gas and collect the flask full (*see* "Air," *Directions, page* 41).

Slightly raise the flask, but keep the mouth still below the surface of the water, and slip over it a greased glass plate.

Invert the flask, wrap round it a thick cloth, and rapidly substitute a piece of wet filter paper for the glass plate, light a taper, pierce a small hole in the wet paper with a wire and apply the light to the mouth of the flask. What is the result?

(2) Repeat (1), but only pour 50 c.c. of water into the flask before inverting it over the beehive cell, so that the gas collected will be mixed with four-fifths its bulk of air.

Be careful to direct the mouth of the flask well away from the face before applying the light, and be prepared for a slight explosion instead of the flame which resulted at this stage in (1).

What lesson does this teach upon the conditions which promote an explosion of gas, and how should this be applied when a smell of gas in the house draws attention to the leakage?

Note.—In all cases of suspected gas leakage turn the gas off at the main and set all doors and windows open to remove accumulated gas by a free current of air before testing the pipes or introducing a light. Coal gas is explosive only when combined with four or more times its bulk of air, it then becomes very dangerous in the presence of lights.

(*C*) Examine a petroleum (paraffin) oil lamp, (1) as to its construction, (2) the means by which the oil employed is vapourized.

(1) The lamp should be made of metal or of some other material not easily broken. If constructed of metal or other good conducting material this should be well insulated from the burner by the use of a long neck.

The oil reservoir should be made to clip securely into the cup or sconce into which it fits, so that there is little risk of its becoming detached.

The stand or pedestal should be heavily weighted to reduce any risk of the lamp being overturned. The burner should be screwed on, not merely riveted or cemented, the screw should be of a good thread and have at least four complete turns round the neck of the reservoir.

The actual burner containing the wick should be continued in the form of a tube almost to the bottom of the reservoir, to prevent the possibility of a hot wick falling into the oil and thus igniting the vapour rising from the oil, so causing an explosion through contact with the heated wick.

(2) Observe as follows the use made of the principle of capillarity to conduct oil from the reservoir to the surface ("A Study of Soils," III. (*B*), *page* 577).

Introduce a new, dry wick into the burner, screw this into the reservoir and note the rise of the oil through the threads of which the wick is composed.

Light the wick, or more accurately the inflammable vapour which is given off from the oil, as soon as the flame approaches the wick, and shelter the flame with the chimney. The chimney regulates the supply of air, in conjunction with the provision made in the burner to admit air to the flame.

Which parts of the burner are designed to prevent the fall of any particles of heated wick into the oil reservoir and to extinguish the flame when required ?

NOTE.—Petroleum may be defined as a product of natural distillation; the hydrocarbons of which it is composed being nearly all liquid at ordinary temperature.

The risks incidental to the use of petroleum oil are explosions due, (1) to using oil with too low a flashing point, so that the upper part of the containing vessel may be filled with dangerous vapour; (2) to such a construction of a lamp as to render it easy to turn a glowing wick into this vapour in careless attempts to extinguish it.

Petroleum lamp accidents may be attributed to the breaking, through careless handling, of the thin glass reservoirs so largely used; from their use when these reservoirs are cracked, or when the wick in a flat wick burner-tube is too small; from want of care in keeping the interior of the burner clean, and from the general ignorance of the public as to the character of petroleum, the proper use of lamps, and the low flashing point of cheap oil.

Lamps give a sustained and brilliant light when properly trimmed and lighted, but a small departure from the position of the wicks will cause a very offensive penetrating odour, and the accidental omission to light one wick of a Duplex burner has caused explosions.

Lamps are sometimes condemned because the accumulation of the hot products of combustion is usually at a lower level than is the case with gas or electric light, and thus diminishes the cubic space immediately available for respiratory purposes. On the other hand there is less burning going on in the case of lamps, because the illumination is more local.

The advantages of electric light are numerous. It has almost the defining power of daylight, it gives but little heat, and may be so arranged as to consume no oxygen, while it yields no noxious or destructive substances; but it has one serious disadvantage, that of cost.

For domestic use, the various incandescent lamps contain carbon (or other) filaments in sealed globes connected at each extremity to a fine wire of platinum; this platinum, passing through some insulating material in the stem, is united to the carbon in a variety of ways, and constitutes the means of connecting it electrically with the conductors of the electrical current external to the lamp.

(*D*) *To Test the Flash Point of Oil.*

(1) Take a tin cup one-fourth full of water. Insert a thermometer, and add boiling water till the temperature reaches 37·8° C. (100° F.). Now add half a teaspoonful of paraffin oil and try to light the vapour with a lighted taper without touching the oil. If it takes fire it is unsafe for domestic use.

(2) *The Fire Test for Oil.*—Place the tin cup on a sand-bath over a Bunsen burner and raise the temperature of its contents from 16° to 17° C. (about 30° F.) above that directed in (1).

Now apply a lighted taper to the oil and it will ignite. Throw a handful of sand over the burning oil. What is the result?

NOTE.—The "flash point" of oil is the term applied to the temperature at which an oil gives off vapours fast enough for it to form an inflammable mixture with the surrounding air.

The temperature varies widely, because oils are highly complicated mixtures, of which the components are of very varying degrees of volatility. If crude oil be heated in a still, the vapour of the more volatile constituents can be conducted to and precipitated in a condensing tank. These products soon evaporate if left exposed to the open air, and are highly inflammable. The "heavy" oil residue becomes comparatively difficult to burn, because the more volatile portion has been removed and also on account of its thicker consistency, which means that it is less rapidly absorbed or pumped up by the lamp wick.

The workable safety point of an illuminating mineral oil is that its vapour should not inflame until the oil is raised to a temperature of 37·8° C. (100° F.), in which case the flash point would be far above the temperature of the room or of that likely to be attained in the oil reservoir of the lamp itself.

The "flash point" of an oil depends on the dimensions and character of the apparatus used, and the term has only a legal meaning when the test is carried out in the "Abel" Flash point apparatus authorized by the Government.

The Petroleum Acts now in force allow a "flash point" of but 22·5° C. (73° F.). The number of lamp accidents

which occur annually among those who burn cheap oils lead to a wish that the standard could be raised to that required in the United States, 37·8° C. (100° F.).

The fire test is the temperature at which the oil itself will ignite. It is usually from 16° to 17° C. (30° F.) above that of the flash point.

Impress the fact that sand or earth should be employed to extinguish burning oil, if water be used the burning oil floats on the surface and is simply spread out over a wider area than otherwise would occur.

VI.—The Size and Position of Windows.

APPARATUS: *Foot rule or cm. measure.*

(*A*) *Window Surface and Floor Area.*

Measure (*a*) the area of the floor and (*b*) the area of the windows in your classroom, sitting-room, and bedroom.

What proportion does (*a*) bear to (*b*) in each case.

For the purposes of this calculation any portion of glass must be disregarded which is habitually covered by opaque blinds or curtains.

NOTE.—If a room is to be adequately lighted the desirable amount of window space as compared with floor space is from one-fourth to one-sixth. A less proportion is insufficient (1) to promote the chemical changes in the body which foster health and cheerfulness; (2) to retard or prevent the growth of unwholesome micro-organisms in the air, floor, walls, or furnishing of the room; (3) to ensure that degree of adequate illumination which promotes cleanliness, by exposing the presence of dust and dirt.

There is but one objection to having windows of the largest size compatible with the strength of the building, *viz.*, the cooling effect of a large area of glass. It is laid down that about 9 square decimetres of glass (1 square foot) will cool about 47 cubic decimetres (1 cubic foot) of air as many degrees per minute as the internal air exceeds in temperature the external air. For this reason radiators are placed beneath the windows in large rooms, so that the air is warmed by passing over them as it falls chilled by impinging on the cold glass. This objection can be entirely surmounted during daylight hours by the use of double windows and after nightfall by covering the glass with wooden shutters.

(*B*) *The Position and Shape of Windows.*

Measure (*a*) the distance between the bottom of the windows and the floor; this should be from 1·06 metres (3 ft. 6 ins.) to 1·21 metres (4 feet): (*b*) the distance between the top of the windows and the ceiling, this should be *nil* or at most 15 cms. (6 ins.): (*c*) the amount of window area sacrificed to sash frames, mullions or fancy settings (such as are found in latticed windows), or to arching or rounded corners.

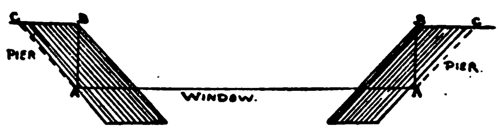

FIG. 123.

NOTE.—If the window sills are nearer the floor than 1·06 metres (3 ft. 6 ins.) the light will enter below or on a level with the eyes of the occupants of the room and produce injurious reflections. If they are more than 1·21 metres (4 feet) from the floor the amount of glass surface is seriously reduced, neither can children look out of the windows, a real deprivation to eyes which require the rest of periodical spells of distant vision, besides the loss of a useful source of interest.

The higher the window extends near the ceiling the better are the conditions for the free admission of light and air. It has been proved that "the upper fourth of a window furnishes one third of the light coming through the whole window."—*Ed. Shaw.*

The practice, among cheap builders, of glazing this portion of the window with coloured glass, or the habit, common among ignorant housewives, of intercepting the top light by valances and draperies cannot be too strongly condemned.

Windows arched at the top come under the same condemnation. Transoms, heavy frames, etc., are also all undesirable on account of reducing the area of transparent glass.

Piers and mullions between windows should be small in order to admit the light so far as possible as a unit. *Fig.* 123 (after Rowe) illustrates also the great gain which follows the bevelling off of window frames, lintels and the sides of the piers and mullions.

VII.—Relationship of Height of Building to Width of Street.

APPARATUS: *Stick; foot rule or cm. measure.*

(*A*) (1) Measure the width of two or three specified streets in the neighbourhood.

(2) Estimate also the height of the houses with which they are lined by "the stick and shadow" method, illustrated in *Fig.* 124.

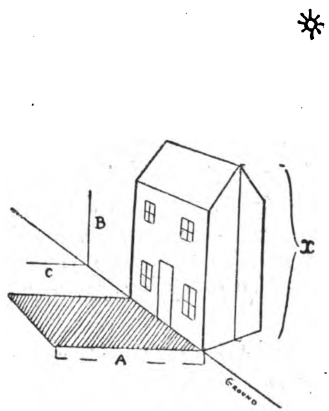

FIG. 124.

Support a stick of known length in a line with the base of the house of which it is desired to calculate the height, and take the exact length of the shadow it casts with a centimetre measure. Then measure with equal accuracy the length of the shadow thrown by the house. As the length of the stick shadow is to the height of the stick, so is the length of the house shadow to the height of the house.

(3) Note the direction of the orientation of these streets. Do they run north and south or east and west?

(4) Calculate the number of hours sunshine which each street will enjoy upon the estimate made by Dr. J. F. J. Sykes, "Streets as wide as the houses are high will secure six hours sunshine in streets at all angles to the meridan at the

summer solstice, and four hours sunshine in meridianal streets at the equinox; the increase in the width to one and a half times the height of the houses will secure six hours sunshine in all streets at the equinox, and three hours in meridianal streets at the winter solstice; if the width of the street be increased to $2\frac{1}{2}$ times the height of the houses, an additional hour of sunlight will be gained in north and south streets at the winter solstice, but it is not until the street is widened to $3\frac{3}{4}$ times the height of the houses that an hour's sunshine is obtained upon the lower parts of houses in east and west streets in mid-winter.

"The angle of 45° for the fronts of buildings on the street, limiting the depth to the width, in London, is reached by the sun's rays near the end of the first week in September and April respectively, so that during about five summer months of the year they are above this angle, and during seven winter months below it. The angle at the vernal and autumnal equinox is $38\frac{1}{2}$°."—(*"Public Health and Architecture," in "Public Health," December, 1904*). (*Fig.* 125.)

NOTE.—The following is the formula upon which the directions given in (2) are based.

$$x = \frac{B \times A}{C} \quad (\textit{See Fig. } 124).$$

As C is to B so is A to X; substitute in this formula the values for the three *known* distances and x is found from them. It is scarcely necessary to add that the distances must all be expressed in similar units, metres and decimetres, or yards, feet, and inches.

Trélat considers the rays of the middle third of the arc as the most valuable for lighting interiors because "the strong rays of the zenith falling vertically scarcely enter the window, and the rays of the horizon which penetrate most deeply into an interior arc are the feeblest and the least useful, whereas the rays of the median zone of the heaven possess neither the weakness of the horizontal nor the impenetrable direction of the vertical, but have an obliquity insuring a moderate distance of penetration and sufficient intensity to insure fair purification. In order to admit the parallel rays of the median zone into a ground-floor

room, **"the width of the streets should be one-and-a-**half times the height of the houses that border them. In any case there is a general consensus of opinion in most countries that streets of less width than depth are insalubrious, and the London Building Act of 1894, prohibits the raising of buildings in streets laid out since 1862 higher than the width of the street, and the raising of buildings in other streets higher than eighty feet without the consent of the London County Council."

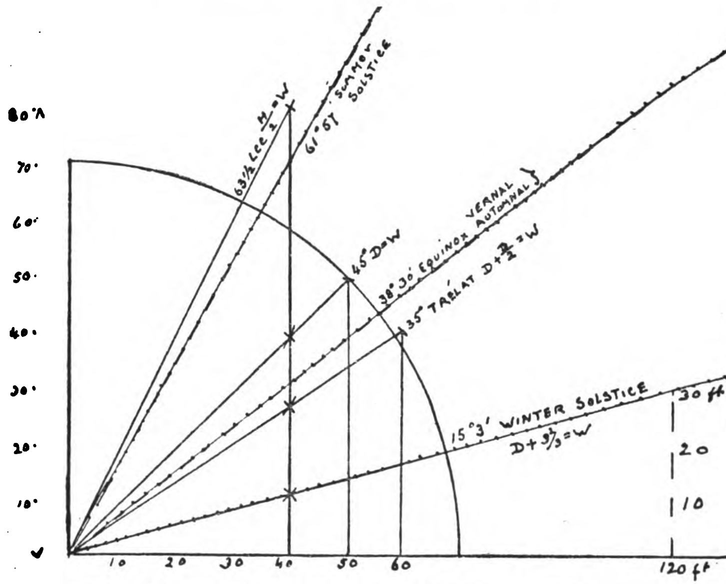

FIG. 125.—Diagram (after Sykes) showing angles of sunshine in London at noon at different seasons, with buildings of different heights.

"The angle of 35° adopted by Trélat (*Fig*. 125), in order to insure sufficient penetration into ground-floor rooms and to secure streets half as wide again as they are deep would obtain sunshine to the lowest point of the vertical line for about twenty-five and twenty-six additional days at each end of the summer months, extending the sunshine period to nearly twenty-eight weeks or approaching seven solar months."

The results upon the inhabitants, more especially upon children, of living in deep valleys or in the basements of high blocks or in narrow streets are invariably evident in deficient vital energy, often in defective mental development and in the prevalence of infectious diseases, such as pthisis in its many forms. Sanitary authorities are called upon to-day to expend large sums in slum districts upon efforts to remedy the ignorance of former generations in respect of the close connection between health, efficiency, light and air.

XXIX.—HOUSE SANITATION AND CLEANLINESS.

Water supply and drainage system. Pipes, traps, sanitary conveniences, lavatories, and dustbins. Methods of sewage disposal. Domestic cleanliness.

I.—Inspection of the Water Supply and Drainage System of a House or School.

MATERIALS: *Corrugated paper; chaff or bran; string; label; litmus paper; hydrochloric acid.*

APPARATUS: *Bottle and rubber cork; thermometer; funnel; round biscuit tin; scaled ruler; weights; rain gauge; basket.*

(*A*) Repeat "BEVERAGES," I. "Water" (*A*), *pp*. 408-11.

(*B*) The provision for an adequate water supply. Enquire as to

(1) The source:—River, lake, or spring.
Reservoir.
Wells—Surface, Deep, Artesian.
Rainfall.

(2) The supply:—Constant.
Intermittent; if intermittent, method of storage (cistern, water-butt, etc.).

NOTE.—(*a*) A fair average domestic supply of water per head daily is about 76 litres (17 gallons) which allows for a bath and for the water-carriage system of drainage. But it is usual to include in such calculations the additional allowances for horses, cattle, industrial processes and municipal purposes in urban districts and towns, which raise the total daily requirements to 90 to 225 litres (20 to 50 gallons) per head of the population.

The rainfall is ultimately the source of all water supply, but the product is only described as rainwater when caught upon artifically prepared surfaces.

Water from deep subterranean sources (as springs, artesian and deep wells), is usually wholesome and abundant, whereas so-called "surface-water" from brooks, rivers, lakes or shallow wells is unsafe for drinking purposes, owing to organic pollutions. It is also frequently as variable and unreliable in quantity as it is in quality. Shallow wells must be emphatically condemned. (*Fig.* 101.)

A visit should be arranged, if possible, to a water reservoir, in order that the system of sand filtration and the protective influence of microbial action can be explained.

Point out the imperative necessity for conducting the filtration of river waters in a strictly scientific manner, and of placing such filtration works under the control of specially trained men.

Water may become polluted at the source, in transit (*e.g.*, by leaking sewers or cesspits), and during storage by being kept in filthy cisterns or barrels.

(*b*) A constant supply of water from a Water Company's main is the most satisfactory domestic arrangement. Where the supply is intermittent and the pipes are, or may be, empty of water for some hours at a time, there is not only considerable risk of suction of foul gases into the pipes, but cisterns with all their disadvantages are necessary for storage purposes. Under all circumstances, however, cisterns must be fitted to water-closets, to obviate the danger of impure air or water being sucked back into the pipes.

The storage cistern, when necessary, should be located well away from the sanitary arrangements, and preferably should be placed in a space or apartment with a north aspect, well lighted and well ventilated, lined with impervious material (cement or tiles), with a lead safe beneath it as a safeguard against leakage or overflow.

All cisterns should be provided with a well-fitting wooden cover, having a small door over the ball-cock for repairs.

Porcelain enamelled stoneware cisterns are the ideal, but their weight, liability to fracture and small size constitute them a luxury.

Fire-clay, salt-glazed cisterns, though otherwise satisfactory, are liable to be slightly porous. Slate cisterns rank next in worth, but are heavy, liable to leak, and expensive,

while if jointed with red lead serious risk of lead poisoning exists. Large cast iron and wrought iron cisterns are good, but, when small, prove very dirty in use; they must always be washed inside with lime or Portland cement. Enamelled iron cisterns are reliable, but galvanized wrought iron cisterns are those in general use. Though in most respects satisfactory, a caution should be given that certain exceptional waters, when stored in them, may set up galvanic action throughout the system.

Wood cisterns lined with sheet zinc are quite unsuitable for the storage of water and are as objectionable as wooden water butts.

Cisterns should have their contents run off and their interiors well cleaned with a soft mop every six months, the water being then allowed to run through until it issues in a perfectly clear stream.

Look for the overflow pipes from all cisterns; these should be carried through the nearest wall, cut off short and discharge into the open air, so that any overflow attracts immediate attention. (*Fig.* 127.)

Rain-water cannot be safely stored in lead, zinc, iron or galvanized iron tanks.

(*C*) *The Use of a Rain Gauge.*

Examine the parts of a rain gauge.

(1) The circular copper funnel with its long tube. What is its diameter? Calculate from this the area of the gauge.

(2) The metal receiver.

(3) The outer case, which when the instrument is in use is partially sunk in the soil.

(4) The graduated glass vessel, of which the graduations must be proportionate to the area of the gauge, they will be in tenths or in half-inches according to the system of measurement employed, metric or British.

Choose a well-exposed position, clear of all houses, trees or other objects of which the height is greater than their distance from the instrument; sink (3) in the soil with the rim about 30 cms. (1 foot) above the earth.

Drain daily into (4) any rain which collects in (2), and with the aid of the graduations calculate the amount of such rainfall as follows :—

If the diameter of the funnel be 20 cms. (8 inches) its receiving area will be 321 sq. cms. (50·26 sq. inches) therefore a rainfall of 2·5 cms. (1 inch) over the district would allow 836 cubic cms. (50·26 cubic inches or 29½ fluid ozs.) of water to be collected in the gauge.

Such a rainfall is unusual in this climate, consequently the water in (4) will more often be scarcely measurable or amount to but tenths, or less, of an inch.

NOTE.—It is quite easy to make a perfectly efficient rain gauge with a round biscuit tin and a funnel, and to measure the rainfall with accuracy if the receiving area be known and the volume of water received be measured, basing the calculations on the fact that 1·728 cubic inch equals 1 fluid oz., and that 1 cubic centimetre is the equivalent of ·06 cubic inch. Thus

$$\frac{\text{c.cs. of rain collected} \times \cdot 06}{\text{area of receiving vessel in square inches}} = \text{inches of rain.}$$

If the diameter of the funnel be 12·50 cms. (5 ins.) the receiving area is only 125·6 sq. cms. (19·63 sq. ins.) and 2·5 cms. (1 in.) of rainfall would represent 368·5 cubic cms. (19·63 cubic ins. or 13 fluid ozs.)

Care is necessary to avoid evaporation from the receiver. To check this, the long narrow tube which passes from the funnel into the receiver usually has its end more or less curled up.

(*D*) *To Collect a Sample of Water to submit for Analysis.*

(1) Purchase a new bottle to hold at least 1 litre; what is known as a Winchester quart is usually employed for this purpose; also a new cork, preferably rubber; in either case in must be well boiled before use.

Rinse the bottle very thoroughly with dilute hydrochloric acid; then wash it well in *boiled* water until the washings when tested with delicate litmus paper give no acid re-action.

Drain the bottle dry, insert the cork, attach one string firmly to the neck of the bottle and a second to the cork.

(2) Proceed to the well, stream, river, cistern or other sourse of supply, attach a weight and a string to a thermometer and immerse the instrument well beneath the surface for ten minutes, withdraw it and record the temperature of the water below the surface.

(3) Push the bottle well under the water, remove the cork by dragging on the string, fill the bottle brimful, withdraw it, instantly insert the cork and pack the bottle in a basket previously prepared, and lined with corrugated paper, chaff, bran or other suitable insulating material.

(4) Attach a strong label to the parcel, and enclose in it clearly written information upon the following points, and despatch the parcel to the analyst with the least possible delay, keeping it meanwhile in a cool place.

Label. Temperature of water when taken.
Date and hour of collection.
Method of collection.
Reason for desiring analysis.
Source of water.
Nature of, and distance from, any evident source of pollution.
Geological character of the soil and subsoil.
Rainfall in general terms.
Name and address of sender.

Should it be desired to send a sample of water drawn from a pump or tap the procedure would be in all respects the same, except that the water must be allowed to flow two or three minutes before the cork is withdrawn and the water received in to the bottle, in order to ensure that it has not been lying for some hours in the pipes between the source of supply and the outlet.

(*E*) *Inspection of the Drainage System of a House or School.*

Points to observe:—

(1) Line and fall of drains. It is a convenience for householders if a plan be available such as is shown in *Fig.* 126, but the fall of the drains can be roughly

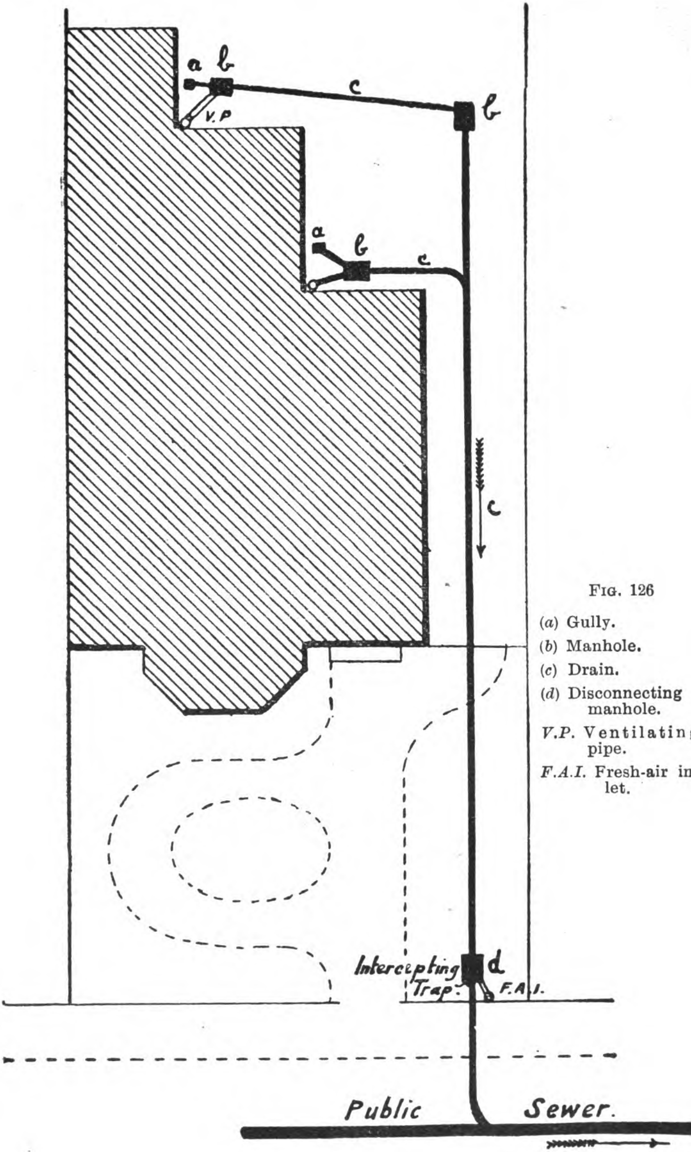

FIG. 126

(a) Gully.

(b) Manhole.

(c) Drain.

(d) Disconnecting manhole.

V.P. Ventilating pipe.

F.A.I. Fresh-air inlet.

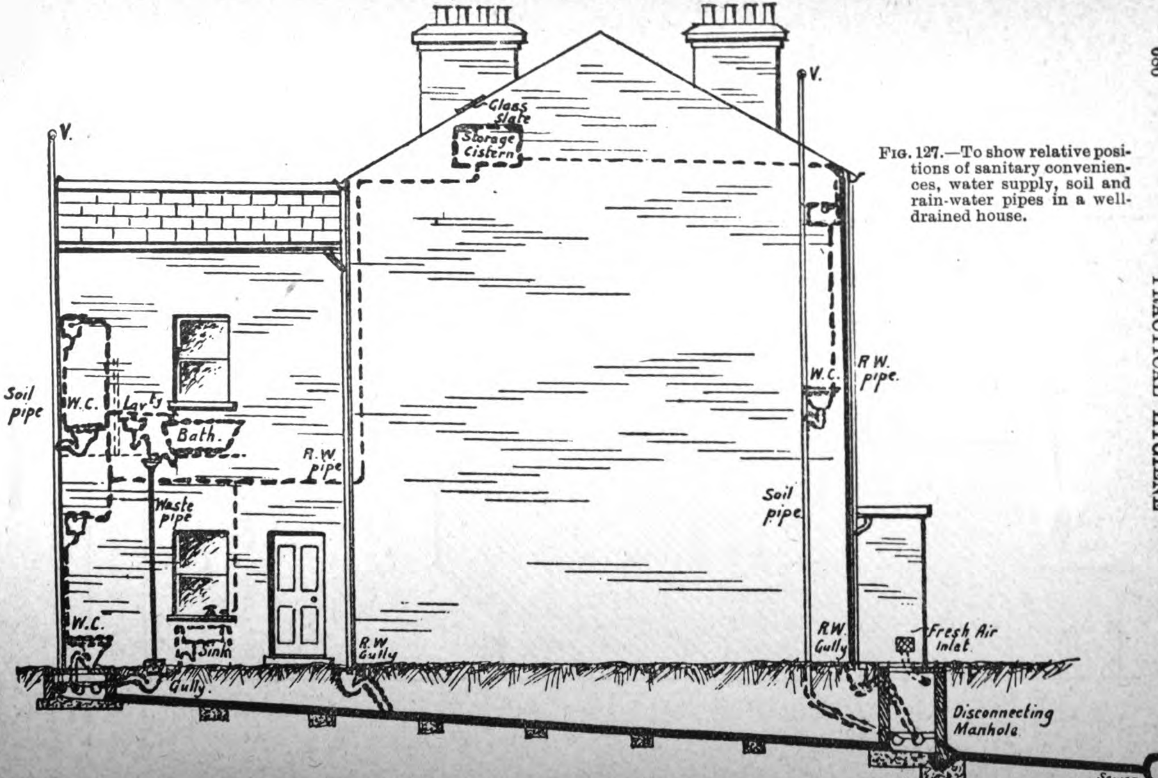

FIG. 127.—To show relative positions of sanitary conveniences, water supply, soil and rain-water pipes in a well-drained house.

arrived at if one person discharges a closet or empties a bucket down the w.c. pan, and the speed of the flow be noted by an observer stationed at the manhole.

(2) Position of manhole or inspection chamber.

(3) Angle of junction pipes.

(4) Situation of pipes:—

(*a*) Soil pipe;
(*b*) Anti-syphonage and ventilation pipes;
(*c*) Rainwater pipes;
(*d*) Waste pipes from sink, bath, etc.;
(*e*) Overflow pipes from cisterns, bath, etc.

(5) Situation and shape of traps (syphon, gully and disconnecting).

(6) Relative position of bathroom, water closets, kitchen sink and larder; the provision for their ventilation.

(7) Character of fittings inside the house-joints, casings, etc.

(8) Amount of flush for closet. Special cistern for w.c. To what degree do the arrangements inspected agree with, or differ from, the following recognized rules respecting drainage and other sanitary arrangements which many Local Authorities require to be observed by builders?

(*a*) All drains and soil pipes shall, as far as possible, be kept outside the house.

(*b*) The underground drains shall be made of sound, glazed-stoneware pipes or cast iron, with well-fitted joints made water-tight with Portland cement or other approved material. The main drains shall be 6 in. diameter, and 4 in. branches.

(*c*) They shall be laid evenly with a regular gradient upon a bed of concrete.

(*d*) They shall have no sharp curves; and especially any portion that may be situated under the house shall be laid, where practicable, in a direct line and without junctions. (*Fig*. 126.)

(*e*) The main drain shall be disconnected from the sewer by an approved interceptor. (*Fig.* 128.)

(*f*) The drains shall, where practicable, be ventilated by a fresh air inlet placed in the main drain as near as possible to the Interceptor, and by outlet shafts of not less than 4 in. in diameter, prolonged directly upwards from the soil pipes outside the house to the highest point of the roof, or at least three feet from the top of the highest window. The position of the air inlet to be pointed out. (*Fig.* 127.)

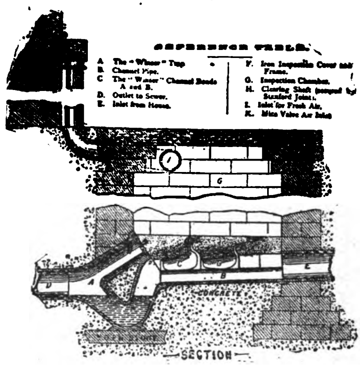

FIG. 128.*

(*g*) Every glazed-stoneware drain carried under a house or building must be bedded in, and covered over, with not less than 6 in. of concrete, composed of one of Portland cement to five of clean pit gravel; an extra thickness of concrete shall be put in all cases where the drain is laid on "made" ground, but no concrete is required either under or over drains when cast iron pipes are employed and these are jointed as in water mains. It is, however, a usual precaution to support each 9 ft. length of pipe (*a*) by two blocks of concrete (*b*) to prevent undue strain on the joints from settling of the soil or foundations. (*Fig.* 129).

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(*h*) An Inspection chamber shall, where practicable, be provided between the Interceptor and the fresh air inlet. (*Fig.* 128.)

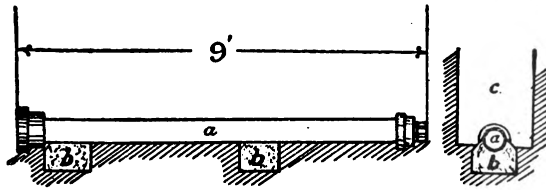

FIG. 129.

(*a*) Iron drain-pipe. (*b*) Concrete block. (*c*) Trench.

(*j*) Rain-water pipes, sink pipes, and waste-water pipes of all kinds shall discharge with open ends outside the house into a stoneware syphon gully communicating directly with the underground drain. (*Fig.* 127.)

(*k*) All sink pipes, as also soil pipes, shall, as far as practicable, have no sharp curves.

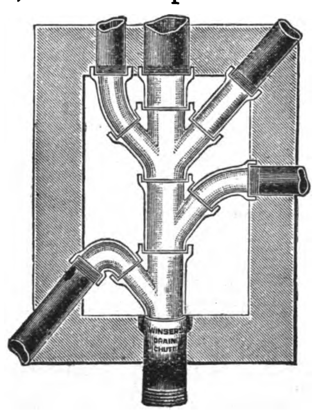

FIG. 130.*

(*l*) Proper **Y** junctions shall, in all cases, be made in connection with all underground drains. No right-angle junctions can be allowed. (*Fig.* 130.)

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(*m*) Water closets shall have at least one external wall, and be properly ventilated by windows and air bricks communicating directly with the external air.

(*n*) Every waste-pipe from a single fitting ought to be provided with a trap as close as possible to the fitting; this is important, otherwise the effluvia from decomposing deposits within the pipe will be carried into the house.

(*o*) Waste water from any one fitting must not be made to pass through more than one trap on its way to the external gully.

(*p*) The traps of all long waste-pipes and of all waste-pipes receiving discharges from more than one fitting, ought to be ventilated to prevent syphonage. This does not so much apply when the waste length is short, but when the length is considerable there is a risk of traps under such fittings being syphoned out.

All such pipes ought to be carried up straight and full bore as ventilation pipes (*Fig.* 127, *v.*). Bear in mind that every bend in a pipe reduces its ventilating capacity by one half.

(*q*) Waste-pipes ought always to be exposed to view; preferably they are fixed outside a house and they should be adequately supported to prevent sagging.

(*r*) Joints ought to be in positions where they can be seen, in order that leakages may attract attention and be easy to repair.

(*s*) Overflow pipes and waste pipes from "safes" (lead traps below cisterns and baths), should be carried through the nearest external wall and cut off short.

NOTE.—Drains made of glazed earthenware pipes, though they are non-absorbent and enduring, cannot stand the stringent modern tests for house drains, they are therefore increasingly superseded by cast iron drains, which will stand tests (by water) with absolute certainty, are not expensive, are easily manipulated, lend themselves admirably to difficult or

complicated situations and are not subject to breakage by shocks. In addition, iron pipes possess the great advantage of being made in long lengths, thereby reducing the number of joints, which are *the* chief source of weakness in drains. The pipes should be coated inside and out with Dr. Angus Smith's compound, or better still with glass enamel.

As sewage forms a protective coating inside iron pipes no sign of interior rusting has been observed in inclined and properly coated cast iron pipes, even after many years of use. Lead soil-pipes are very troublesome owing to the expansion or contraction which occurs when hot water or cold water is thrown down the closets. When this metal is used for pipes of inclination they require support throughout their entire length to avoid sagging. Lead pipes must always be "drawn" never be "seamed," or leakages may occur.

Galvanized iron pipes lined with vitreous glaze or tin (the "Health" pipe), are absolutely satisfactory and are considered the best form of pipe for all drinking waters.

The service pipes from the cistern should be so arranged that, by means of a stop cock immediately under the cistern, or as near thereto as possible, the water may be emptied whenever necessary, either for repairs, or on the approach of frost. This arrangement ought never to be omitted.

Every pipe should be fixed in such a way as to allow it to empty itself completely when the supply has been shut off at the cistern, by means of the stop-cock above referred to, and when the tap at the outlet has been opened.

Water pipes as a rule, should not be fixed in positions where they are specially liable to draughts of cold air—not immediately beneath a window, for instance, because in cold weather the current of cold air passing downward from the window, even though closed, is very liable, under certain conditions, to cause the water to freeze in the pipes.

II.—Pipes, Traps, Sanitary Conveniences, etc.

MATERIALS: *Models of pipes, traps, etc.* (see (*A*) NOTE); *models of sanitary conveniences; lead pipe; soda; potash; potato parings; tea leaves; cabbage leaves; kitchen scraps; dry ashes; scraps of paper; straw; earth; broth.*

APPARATUS: *Wide mouthed bottles with corks; small flower pot; beakers; glass tubing; glass syphon trap; funnel; small dish; rubber tubing; balance; retort-stand; air-oven; Bunsen burner.*

(*A*) **Examine the specimens of pipes, traps and joints. Enumerate as follows:—**

(1) The purpose for which each specimen would be used.

(2) The position in which such specimens would be used.

(3) Any special advantages or disadvantages you may notice in the models under examination.

Purpose.	Position.	Advantages.	Disadvantages.

NOTE.—The specimens should include short lengths of model pipes, earthenware, cast iron, cast iron protected by the Barff and Angus Smith methods, lead with drawn and seamed junctions, gulley and disconnecting syphon traps, a "wiped," a "copper bit," and a "blown joint" on lead piping.

All the points mentioned can be clearly demonstrated by the aid of Knight's House Drainage Ventilation Model, No. 1, which should, if possible, be employed for the purpose, otherwise among young pupils very confused ideas are liable to exist.

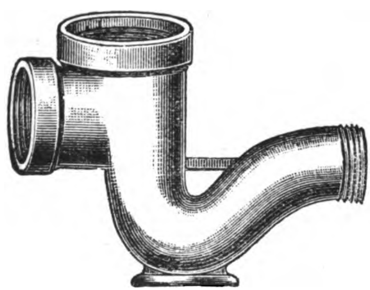

FIG. 131.*—Buchan's Disconnecting Trap.

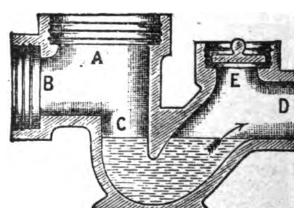

FIG. 132.*—Section.

Traps are used to interpose a water-seal to the passage of foul air from drains to and from house pipes, that is they afford a free passage for water and solids but not for gases. All traps must be self-cleansing, therefore the syphon form is the only one admissible (*Fig.* 131). Road gulley traps are the exception to this rule, for they are designed to arrest and collect solid matters which might lead otherwise

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to stoppage in the drains; they are quite unsuited to receive house-slops, which convert them into miniature cesspools (*Fig.* 133).

The sectional area of a trap should be less, certainly not more, than that of the pipe. The curve must be regular and not too sharp. The water line should be low enough to give a sufficient forcing head from any incoming water, and the dip or trappage should be not less than 3·75 cms. (1½ inches). (*Fig.* 132.)

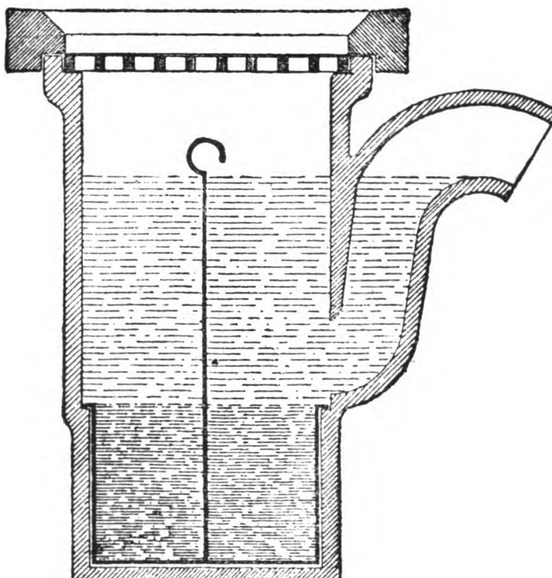

FIG. 133.*—Dean's Silt Gully.

The trap must be properly laid, the outlet, for instance, must be lower than the inlet; it must be in proportion to the size of the pipe, a 10 cms. (4 inch) trap is large enough for a 15 cms. (6 inch) pipe; a too large trap leads to the formation of deposits.

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Traps should be easy of access, and ought to be easily cleansed. Any trap not flushed frequently in summer weather should have a little oil poured down to retard evaporation (*see* "WATER," III. (*C*) (3), NOTE, *page* 64).

Trap ventilation is necessary when:—

(*a*) Two or more fittings discharge into the same stack-pipe (*see* (8), (*p*.), *page* 690).

(*b*) When the branch waste, taken from the trap to its junction with the stack-pipe, is of appreciable length.

(*c*) When there is a long length of discharge pipe leading to the drain from the syphon trap under a sink.

In these cases an anti-syphonage pipe should be taken off the crown of the outlet of all but the highest trap and carried to the exterior through the wall.

The anti-syphonage pipe may be continued up to about 60·94 cms. (2 ft.) above the eaves, or it may be branched into the stack-pipe some few feet above the level of the uppermost fittings, receiving on its way the anti-syphonage pipes of all the other fittings which discharge into the stack-pipe.

Joints in lead water-pipes should always be "wiped" not "blown," indeed the latter should never be permitted in good plumbing. Care should be taken in all joints that the innermost pipe enters the outer in the direction of the current, otherwise the ledge which must necessarily be formed will become a harbour for any dirt or foreign matter that may chance to be in the water.

NOTE.—Consideration of the variations of temperature to which a sink waste-pipe or a bath-waste and their joints are exposed will enable the strain put upon joints in the ordinary process of use to be appreciated. For instance, when a large quantity of very hot water is passed down a pipe the inner part will expand with the heat before this is communicated to the pipe outside it, a compressing influence is thus exerted upon the luting of the joint. On the other hand when the pipes and traps have been heated by a hot water discharge,

if a large quantity of cold water is suddenly run off from the tap, it will cool the upper and inner tube more rapidly than the one outside it and cause it suddenly to contract where before it had expanded. The pipe also will be constantly expanding and contracting. Obviously this alternation of increased and diminished pressure upon the material filling up the joint will, sooner or later cripple the pipe, and render the joint itself insecure. The only way to counteract this effect is to fix the pipe with a bend inside the house, or, in the case of straight vertical pipes outside the house, to provide expansion joints.

(D) *The Principles of Syphonage.*

(1) Take a length of glass tubing 30 cms. (1 ft.) long, heat a portion in the Bunsen burner about 10 cms. (4 in.) from one end and bend the glass at that point. The bent tube will be open at both ends and the legs will be of very unequal length; call the shorter leg (*a*), the longer leg (*b*).

Arrange a beaker (*c*) full of water on a ring of the retort stand, fill the syphon tube with water, closing both orifices with the fingers. Introduce (*a*) below the level of the water in (*c*), remove the finger, place a small dish (*d*) beneath the long limb (*b*), unclose the end and observe the transference of the water from (*c*) to (*d*). For how long does this continue?

Refer to "AIR," I. (*B*), *page* 46. Does this suggest an explanation of the phenomenon?

NOTE.—The water will continue to flow so long as the orifice of (*a*) is beneath the surface of the water in (*c*). The explanation is as follows:—The longer column in (*b*) by superior gravity begins to run out and would produce a vacuum at the upper end. The pressure of the atmosphere on the surface of the water in the beaker, however, prevents this vacuum by forcing the water up the short leg. This in turn follows the water escaping from (*b*), and so a constant flow is set up till the water in the beaker is drawn down to the end of (*a*) when air enters and stops the action.

(2) Examine the shape of a specimen glass syphon trap, which consists of a deeply curved tube like the letter S. Pour in a little coloured water and observe what is techni-

cally described as "a water seal," *i.e.*, when the water reaches a height on each side of the dip in the tube at which it runs away at the lower side of the trap (*Fig.* 182). This depth is usually sufficient to resist the ordinary pressure of sewer gas. It varies with its diameter, but experience has shown that it should be from 5 to 7·50 cms. (2 to 3 ins.) in a pipe of which the diameter is 10 to 12·50 cms. (4 to 5 ins.).

NOTE.—The attention of pupils should be called to the fact that the word "syphon" is a misnomer; an "S"-trap is really an inverted syphon.

(3) To demonstrate that gas under pressure can force a water seal.

Fill the glass syphon trap to the level of what you consider would constitute a good water seal. Connect the end of the syphon with a Bunsen burner by means of rubber tubing. Turn on the gas for five minutes, then observe the results as shown by any change in the odour of the water.

Make the test with the gas :—

(*a*) At ordinary pressure.

(*b*) At increased pressure, which can be effected by compressing the rubber tubing forcibly toward the trap, thus driving the gas into the water under considerable pressure.

(4) Connect the glass syphon trap with a funnel by means of rubber tubing, and clamp it to the retort stand. Fill the funnel with hot greasy water, which should be allowed to flow through the trap into a vessel conveniently placed to receive it.

Allow the greasy water which remains in the trap to get cold and then flush the trap with :

(i.) Cold water;
(ii.) Hot water;
(iii.) Hot water and soda;
(iv.) Hot water and potash.

With which do you obtain the best results, and why?

What lesson does this teach upon the necessity for throwing a pail of hot water (strong with soda) down a sink pipe at the close of each day, if the trap is to be filled with clean water and the air in the room with which it communicates is not to be contaminated with foul gases?

NOTE.—Impress the point that clean water should be always left in traps after use. Hardened grease often interferes with the free flow of waste water and by reason of its decomposition causes offensive and unwholesome smells.

The screw cap should frequently be removed from the lowest part of the syphon traps which are attached to sinks, preferably once a week, if a thorough cleansing of the pipe is to be effected, or whenever the waste pipe shows, by discharging slowly, that the pipe is becoming foul (*Fig.* 138).

Potash is better than soda for removing accumulations of grease as it forms a soft instead of a hard soap in combination with the fat, and the more soluble compound which results is more easily flushed away with hot water.

(*D*) Examine the models of sanitary conveniences supplied, and observe the arrangements designed for the rapid removal of solid and liquid excretions and for the maintenance of cleanly conditions.

NOTE.—Closet apparatus ought to be of the simplest kind consistent with efficiency. The advantages and disadvantages should be pointed out of the three kinds of water closets in common use.

(*a*) The indoor water-closet, valve, hopper and syphonic (*Figs.* 134 and 135).

(*b*) Slop-closets, in which the contents are washed away by the waste liquids of the household.

(*c*) Trough-closets, or those connected with a trough, containing water common to two or more seats, these are also called "latrines" and combined closets (*Fig.* 136).

The chief points in the selection of a water-closet should be enumerated (*Fig.* 135).

(1) A basin of suitable shape to hold sufficient water and of a size to ensure perfect cleanliness of its sides; the back of the basin should be nearly vertical.

(2) The basin should be of plain white stoneware, but in any case of non-absorbent material. All closet pans should be periodically and regularly cleaned with a hard brush

and strong soda and water, or spirits of salts. Brushes specially made for the purpose can be bought at the hardware shops.

(3) The syphon trap should be in one piece with the basin and without angles; the seal of the trap should be from 3 to 5 cms. (1½ to 2 ins.).

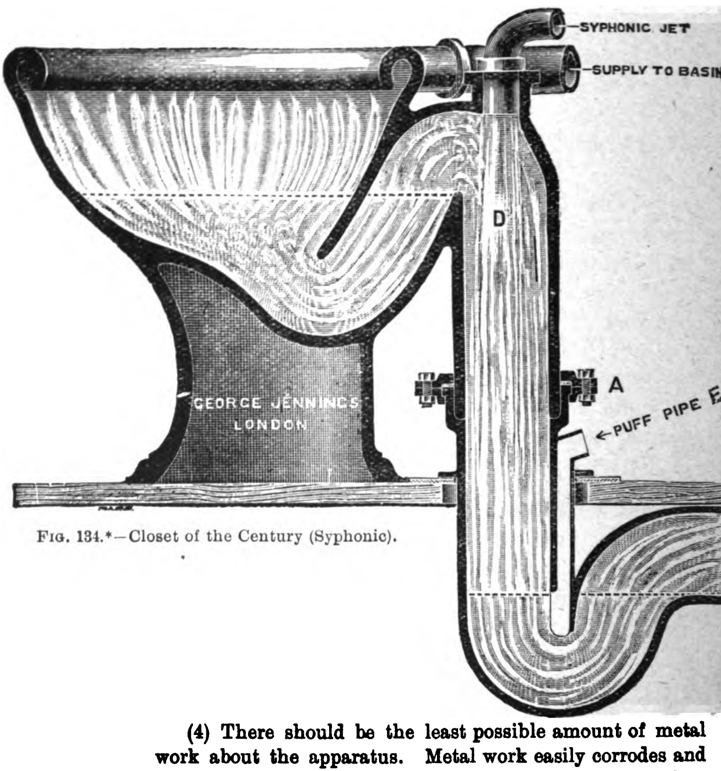

FIG. 134.*—Closet of the Century (Syphonic).

(4) There should be the least possible amount of metal work about the apparatus. Metal work easily corrodes and encourages deposit of offensive matters; it also involves joints, and these are liable to leak.

(5) The flushing rim must be so constructed that the main portion of the flush will be brought to bear upon the trap; it should have a vertical flushing arm.

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(6) The flush should be thoroughly efficient; at least *two* gallons of water is necessary, though three are preferable where the water supply permits.

(7) The connection with the soil-pipe should be *above* the floor line, or preferably outside the house wall.

(8) Refer to the sanitary importance of having all plumbing exposed to view and all joints easy of access, also to the advantages of a very sparing use of wood work in the fitting of closets. Where wood work is indispensable it should be varnished and non-absorbent, and hinged or otherwise fixed so as to be easily removed.

All forms of "Hopper" closet apparatus consist of a funnel-shaped basin with trap, either all in one piece or separate, the latter being occasionally advantageous when the branch from the soil-pipe is at an unusual angle with the front to back line of the basin.

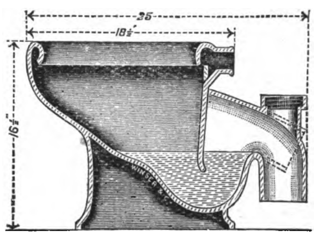

FIG 135.*—Section of Wash-down Closet.

The "short wash-down" hopper is the best kind, being simple and generally suitable. The inside of the basin is however liable to be soiled, because the area of the contained water is not as large as could be desired. The reason given for this defect is that any increase in the water area represents an extra depth of trappage, a combination of conditions for which the 2 gallon water flush allowed by most Water Companies is insufficient to ensure clearing the basin after use.

The intimate relation between the depth of trappage, area of water and the volume of flush are rarely realized, but should be always considered when choosing a pattern of closet.

A class of "Hopper" closets in which syphonic action has been introduced to assist the flush is now being adopted to overcome the objection of a small water area (*Fig.* 134).

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Trappage must still be deep, but clearing is usually effective, though more than a 2 gallon flush is necessary in most instances.

The flushing arrangements of all hopper closets is usually of the waste-preventing cistern type, to meet the requirements of the Water Companies and to ensure an efficient flush. The regulation size is 2 gallons. The object is to give a flush by syphonic action of a required volume of water at a rapid rate; such cisterns should therefore be of a capacity to discharge the required volume of water, they should also be valveless and incorrodible. The discharge pipe should have a diameter of from 3 to 4 cms. (1¼ to 1½ ins.). If the flushing cistern be placed at the back of the seat, instead of several feet above it, a comparatively silent discharge can be obtained.

Two kinds of "Slop" Closets are met with, (1) those in which the waste is allowed to run directly into the basin, or is poured down by hand; (2) those in which, with a view to a better flush, the waste liquid is collected in a suitable contrivance and discharged automatically at intervals.

These closets are objectionable in many ways; the stream of water is often insufficient, the basin is apt to get fouled at the back and sides, improper substances are readily thrown down and block the pipes, while the trap is always full of dirty water and becomes a source of offence.

Slop closets are only allowable where water is scarce. They must only be used out of doors, when the sewers have a good fall, and a public service of water is laid on to each house. They are cheap, consume little water, produce less sewage and are less affected by frost than ordinary water-closets, but cannot be considered as first-rate sanitary fittings.

The "Trough" or Combined closet is usually found in schools, manufactories, and blocks of houses. Connected with the top end of the trough or outlet pipe, and 5 or 6 ft. above it, is an automatic flush tank, and at the other end is a syphon trap (*Fig.* 136).

The drawbacks are:—high original cost, the large quantity of water used, the great noise when flushing occurs, and the absence of training in decent attention to cleanly habits among those who use them.

There are many forms of Tub and Pail closets, to which reference must be made where they are in use.

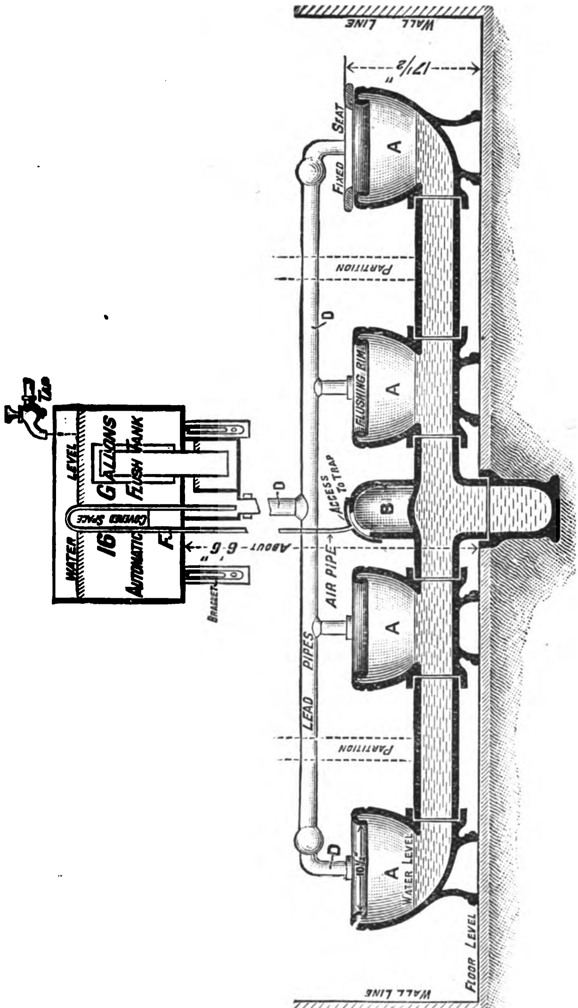

FIG. 136.*—Duckett's Latrine.

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The essential principle in these closets and in middens is the deodorizing of excreta by dry earth or ashes.

The earth closet is the best form (*Fig.* 137). About one and a half pounds of clean dry earth is thrown upon the pail contents, either by hand or automatically. Loamy surface soil, vegetable moulds, shredded peat, dry clay, or brick earth are the best for the purpose, and if properly dried can be used for the purpose again and again, constituting subsequently a most valuable manure. Chalk, gravel and sand are not suitable. The earth must always be *sifted* and *dry*, and no slop water must be added.

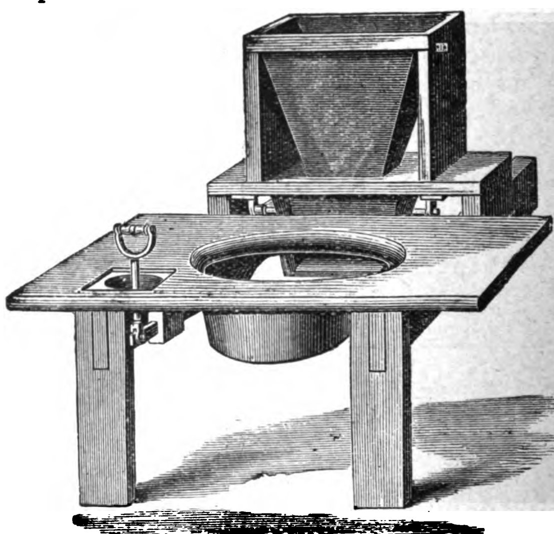

FIG. 137.*—Moule's Earth Closet.

(*E*) *Examination of Lavatories.*

The position, shape and material of baths and lavatory basins should be examined by the pupils, and attention should be directed to the following among many other possible points:—

(1) The advantages of omitting all framed and panelled woodwork, and of fixing baths and basins in such a manner

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as to permit of free access all around and beneath them. Splashings of dirty soapy water accumulate, dry, and cause objectionable smells (*Fig.* 138).

Galvanized painted brackets or iron standards are advisable for sinks and lavatory basins.

Zinc baths must be specially supported with a wooden framework or they get out of shape and the water fails to run off. Iron oxidizes so easily when in contact with moisture that the painting or ordinary enamelling in metal baths is liable to damage and chip off, but a cast-iron bath coated with vitreous enamel is practically indestructible and of all baths of moderate cost is the best.

Water should never be admitted through the same orifice as that used for the outlet of the bath or basin, or for the overflow. The clean water entering must be more or less polluted by, if it does not carry with it, decomposing matter from the soiled surfaces of the pipes. The idea is unpleasant in itself, but in addition ringworm, eczema, and other skin diseases may be thus communicated.

Pivoted or "tip up" basins do not constitute a sanitary form of lavatories on account of the large fouling surface they present in the container in which they are hung.

Two types of fixed basins are in common use, the ordinary shape of the loose basin and the "cabinet top" basin. The best form of lavatory basin has a rim turning upwards and a flushing rim; the soap trays are shallow and incapable of retaining water, draining directly into the basin through a small channel. The most serious difficulty is the concealed and inaccessible overflow pipes with which most baths and lavatory basins are provided. These become "furred" with greasy and soapy deposits, objectionable on account of the noxious odours they generate, a portion of which are given off whenever the appliance is used. The overflow pipe should be accessible at the top for cleaning purposes.

This has been overcome in some of the most modern fittings, where the overflow pipes are broad, as short as possible, are carried into the waste pipe leading from the bath or basin, and have a removable grid, which allows of easy access to the pipe for cleaning purposes (*Fig.* 138).

The lavatories and sanitary conveniences of the school should be examined and tested by the standards laid down.

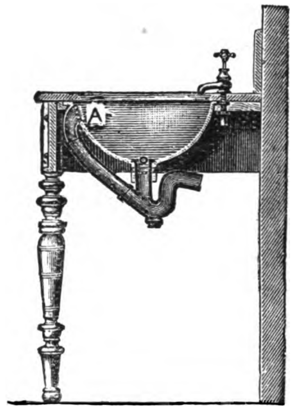

FIG. 138.*—Lavatory with overflow which can be cleansed.

(*F*) *The Function of Dustbins.*

(1) Take three bottles with wide mouths (fruit jars answer the purpose), and label them (*a*), (*b*), (*c*).

Prepare a mixture of potato parings, tea leaves, cabbage leaves and a few kitchen scraps and divide them into two portions. Half fill:—

(*a*) With this mixture; cork, and set aside in a warm place.

(*b*) With dry ashes, scraps of paper and straw; cork, and set aside.

(*c*) With the vegetable mixture after this has been slowly and thoroughly dried under the fire or in the air-oven for some hours; then cork the bottle and set aside with (*a*) and (*b*).

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After 4 or 5 days fit up each bottle as shown in *Fig.* 10, *page* 54, and repeat "AIR," IV. (*C*) (3), *page* 54. Are similar results obtained in each case?

(2) (*a*) Prepare a small flower pot full of earth, pour 3 or 4 c.c. (1 drachm) of broth over its surface and set it aside in a warm place for a week.

(*b*) Fill a vessel of similar size to the flower pot full of water, and add the same quantity of broth; set aside under similar conditions and compare the results in a week.

NOTE.—Warmth and moisture are the great agents that encourage putrefaction, all refuse should therefore be kept dry and not exposed to the sun. Domestic house refuse usually consists of dust, ashes, food scraps (animal and vegetable), waste paper, etc., though dust carts can be only legally required to remove dust, ashes, and a reasonable amount of waste paper.

All food scraps *should be burnt*. When, owing to the use of gas stoves this is not possible, they should be well desiccated before being thrown into the ashpit or dustbin. These receptacles should consist of impervious materials, and should be protected from wet or sun by close fitting coverings.

A model of the "Sanitary Dust-bin" advocated by the London County Council should be examined by the pupils, and its advantages and disadvantages should be considered. It is impervious (galvanized iron), cylindrical in shape, is furnished with a lid, is portable and not too large, so that refuse cannot accumulate for long together, but, in consequence of the general character of house refuse, it becomes fouled, is rarely if ever cleansed, the lid is often not replaced in position and, where the "dust" is not collected with desirable frequency, the contents overflow and pollute the soil. The ideal ash-bin has yet to be invented, though the improvements affected by the Gorton Sanitary Appliance Company, the Sanitaries Ltd., and others, indicate lines which it is to be hoped will be followed up.

A visit should be made to a Public Refuse Destructor, in order that the complete destruction of unwholesome and infectious matter on a large scale may be understood and appreciated.

III.—Methods of Sewage Disposal.

NOTE.—Pupils should be taken to see local methods of sewage disposal. If possible the most modern method, known as the "biological," should be investigated; in this system microbial action is employed in properly prepared bacterial beds to dispose of town sewage in a most satisfactory manner. *Fig.* 139 illustrates a practicable method for the sub-surface

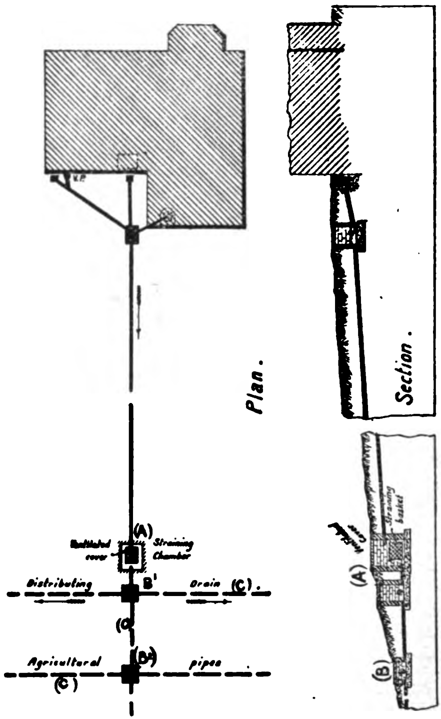

FIG. 139.

disposal of the drainage from houses or institutions in the country. All wastes are carried to a cement-lined tank (A), known as the "straining chamber," situated at some little distance from the house. A pipe leads from the bottom of (A) to a smaller chamber (B), from which (C), a distributing

drain, is carried right and left the whole width of the garden or fields which are to be enriched by the sewage. A similar connection unites (B^1) and (B^2), an arrangement repeated as often as is necessary to meet the requirements of the particular case.

The sewage is discharged intermittently to any portion of the system by means of small hatches in (B^1), (B^2), etc. These are raised or lowered so that the sewage can be led in any required direction along the drains, which are, of course, laid with open or loose joints.

Reference should again be made to the admirable methods advocated by Dr. Vivian Poore for the disposal of house refuse in gardens, in his book on "*Rural Hygiene.*"

IV.—Domestic Cleanliness.

MATERIALS: *Specimens of carpets, etc.; dolls' furniture in different designs; small utensils made of glass, china, etc.* (see (*A*)); *pieces of deal board, etc.* (see (*B*)); *broom; Bissell carpet-sweeper; rugs; feather brush; butter muslin; wool-flocks; horse-hair from new mattress and from one in use; wire dish-cover; soap; rag; oil; kerosene; animal charcoal; nutrient gelatine.*

APPARATUS: *Basins; large glass filter; petrie dishes; pipette; glass bottle; beakers; yard or metre measure; scissors; balance; retort stand; Bunsen burner.*

(*A*) Examine the specimens supplied under the following headings in respect of their—

(*a*) Texture; whether favourable or unfavourable to the collection of dust.

(*b*) Surfaces; absorbent or non-absorbent, rough or smooth.

(*c*) Shape and design; simple or intricate, adapted to their object or unsuitable and inartistic.

Tabulate the specimens according to your estimate of their value in sanitary furnishing, where cleanliness combined with a minimum of labour is the object in view.

	Texture.	Surface.	Shape and Design.
Fabrics.			
Carpets.—			
Pile			
Brussels			
Hemp			
Curtains.—			
Woollens			
Casement cloth			
Muslin or lace			
Chintz or Cretonne			
Coverings.—			
Plush or velvet			
Brocade, silk or wool			
Cretonne or chintz			
Leather			
Oil cloth			
Linoleum			
American cloth			
Matting, cocoa-nut fibre, and straw			
Furniture.—(*Wood and Wicker.*)			
Chairs			
Cabinets			
Tables			
Beds and bedding			
Utensils.			
Glass			
China			
Copper			
Block-tin			
Iron			
Marble			
Flooring and Walls.			
Deal, unpolished			
Deal, stained and polished			
Deal, painted and varnished			
Parquetrie			
Papers of several makes			
Distemper, washable and unwashable			

NOTE.—Healthful furnishing has been defined as that "which in material, construction and finish adds no injurious particles to the air and allows of frequent, thorough and easy cleaning, without the sacrifice of utility and beauty." Care should therefore be exercised to choose, whenever possible, articles or fabrics with non-absorbent surfaces, not only to facilitate cleansing processes, but to minimize the retention in wall-hangings, carpets and furniture of the organic matter, dry or moist, given off from the bodies, clothes and food of the occupants, or the risk of harbouring insect pests, such as flies, gnats, fleas, bugs, black beetles, ants, or moths.

Simplicity of design should be combined with strength in furniture and household utensils. Intricacy of ornamentation, fretwork and chasing, seams and rough surfaces, all add to labour as well as provide places for the collection of dust and dirt.

Polished woodwork and bright metallic or highly glazed surfaces draw attention to deposits of dirt by their diminished gloss or tarnished appearance. Unpolished wood, ordinary distemper and wall papers, woollen curtains, chair covers, carpets, rugs and cushions absorb dirt almost unobserved, and do not recall its presence except to the touch and smell.

Delicate, absorbent surfaces are difficult, expensive and unsatisfactory to clean, while most wool carpets and draperies are too heavy to be often removed for shaking or beating. Mattings or other porous fabrics permit the easy passage of dust, which accumulates beneath them unseen, though it is constantly stirred up into the air by the friction of passing feet, draughts, etc.

Advocate polished wood, parquetrie or linoleums (the latter to be nailed, not glued, down) for floors, with rugs of a size and quality which permit of frequent beating and washing over with a cloth damped with ammonia and water (1 oz. to 2 gallons of water).

Mention should be made of the preparations of non-drying oils now on the market, which, when applied to floors, retain the dust as it falls and prevent it settling on walls and furniture.

Oil-cloth forms a good covering for the walls of kitchens, sculleries, or bath-rooms where glazed tiles are too expensive, and some form of hard finish in a pretty tone of colour is to

be infinitely preferred to ordinary wall papers for all other rooms, as it can be easily wiped down with damp cloths and the surface satisfactorily cleansed.

Limewash, renewed two or three times a year, should be used for larders, cellars and outhouses.

Show drawings of simple, well-designed furniture and direct attention to its advantages, artistic and sanitary. Point out the dust traps represented by old upholstered furniture and elaborate hangings.

(*B*) *The Advantages of Non-absorbent Surfaces.*

Take small pieces of the specimens provided, spill on each a little dirty, greasy water and leave for two hours before further examination.

(1) A piece of deal board (*e.g.*, the lid of a packing case or soap box).

(2) A similar piece of wood polished with Ronuk or with beeswax and turpentine.

(3) Polished wood.
(4) Painted wood.
(5) Linoleum.
(6) Carpet or drugget.
(7) Leather covering.
(8) Chintz curtain.
(9) Glass or china cup.
(10) A tin pot.
(11) An enamelled pan.
(12) A silver spoon.
(13) A wooden spoon.

In which cases has the dirty water been absorbed or non-absorbed ?

Proceed to wash the specimens (1), (4), (5), (6), (8), (9), (10), (11), (12) and (13) with soap and hot water, rub each dry with a soft cloth; rub (2), (3) and (7) with an oiled rag, finish off with a soft dry cloth.

Are the results satisfactory in every case, or is the balance in favour of non-absorbent surfaces?

(*C*) *To Illustrate the Unsuspected Presence of Domestic Dirt.*

(1) An Examination of Bedding.

(i.) Weigh out 10 grams (154·32 grains, or about $\frac{1}{3}$ of an oz.), of the specimen of wool flocks provided, and put it into a bag made of double butter muslin, weigh again and note the weight.

(ii.) Bring 1 litre ($1\frac{3}{4}$ pts.) of water to boiling point, cool to 37·8° C. (100° F.) and rinse the flock thoroughly in this for half-an-hour, kneading and squeezing the bag with hands previously well scrubbed with soap and hot water.

(iii.) Pour off 250 c.c. ($\frac{1}{2}$ pint), of the washings into a basin previously scalded out with boiling water, and wring the bag well over the basin, in order to squeeze out every possible drop of filthy moisture.

Evaporate the washings slowly in the air-oven, until only a thick moist paste remains in the basin.

(iv.) When the contents of the bag have been dried by exposure to the air, weigh again. The diminution of weight from that recorded in (i.) represents the loss occasioned by the washing-out of solid dirt and dye.

(v.) Make a charcoal filter as follows:—

Line a large glass filter (diameter 10 cms. = 4 ins.) with a piece of moist double butter muslin and fill it with tightly packed animal charcoal, previously finely powered, support in a retort stand over a glass beaker. Take the remainder of the washings left from (iii.), and pass them slowly through the charcoal filter.

The decolorization of the filtrate illustrates the amount of dyes present in the sample, which darken the washings in addition to the actual dirt.

(vi.) Prepare four sterilized Petrie dishes (*a*), (*b*), (*c*), (*d*); liquefy a tube of nutrient gelatine with gentle heat. Pour in sufficient gelatine to form a layer in each dish, then add rapidly to:—

(*a*) A sprinkling of flock from the specimen provided before washing.

(*b*) A similar sprinkling from the flock which has been washed and dried, but is still slightly moist.

(*c*) Some particles of the thick paste which results from the slow evaporation of the washings in (iii.).

(*d*) A few drops of the filtrate produced in (v.), which must be added with a pipette while the gelatine is still liquid and combined therewith by gentle rotation.

Set all the cultures aside in a warm, dark place and examine them daily for a week or ten days.

What does their appearance suggest as to the character of the flocks and its suitability for purposes of bedding.

Do the conditions under which bedding is usually kept correspond with those favourable to the development of moulds and bacteria? ("CLEANLINESS," VI., *pp.* 551-3.)

NOTE.—The signs of bacterial activity will be much more evident in (*b*) than in (*a*) in spite of the rinsing process, because of the warmth and moisture to which it has been exposed, conditions which invariably promote the development of moulds and bacteria if present. The growth of liquefying organisms will probably be evident in each culture, but most in (*c*), which will be extremely offensive when uncovered.

Colonies will also develop in (*d*) (which will confirm previous teaching upon the absence of security against germ life in charcoal filters), but from the dilute character of the solution their presence may not be so easy to detect by naked eye examination.

It is advisable to supply samples of different priced flocks to different groups of pupils, and if possible to secure specimens from beds in actual use.

There can be no better object lesson in the importance of the daily airing of bedding, which, if it is to be healthy, ought to be cooled and dried by thorough exposure to the air and sun in order to maintain it in as clean and wholesome a condition as possible.

Flock or "mill puff" beds should be uncompromisingly condemned unless prepared under conditions very different from those which now usually obtain. The substitution of chaff should be recommended where expense is an object, as it is cheap, cleanly, and can be renewed frequently at very small cost; bran is also recommended for the purpose.

(2) Take the samples of horse-hair labelled (*a*) and (*b*)—

(*a*) should be withdrawn from a new mattress;

(*b*) should be pulled from a mattress in use for some time.

Treat these samples in every respect as directed in IV. (*C*), and make three cultures from each specimen—

(*a*) (1) Scatter snippings of horse-hair cut with sterilized scissors over a layer of sterilized gelatine, just before it solidifies in a sterilized Petrie dish.

(*a*) (2) Scatter similar snippings after washing and rinsing.

(*a*) (3) Deposit a few drops of the residue evaporated from the washings which remain from (*a*) (2).

Keep all these cultures under conditions similar to those directed in IV. (*C*).

NOTE.—Moulds will develop in each culture and will be easy of recognition; in some specimens of hair bedding bacteria even of the liquefying type are also present. (*Page* 55.)

Periodical sterilization by stoving, in addition to daily exposure to air and light, are necessary for all classes of bedding, if it is to be kept in a thoroughly wholesome condition.

The following is a brief abstract of the results obtained by Mr. Peter Fyfe at Glasgow from a careful examination of three, new, wool "mill puff" or flock mattresses, of which full details are available in the "*Transactions of the Royal Sanitary Institute*," *Vol. XXVII., No. 12, January, 1907.*

Bed I., weighed 36 lbs. before rinsing and lost 5½ lbs. of dirt in the process. Bed II., lost 4½ lbs., Bed III., lost 3 lbs.

A chemical analysis of the washings showed that these contained "more organic matter capable of rapidly undergoing putrefaction than crude sewage;" further, "it is plainly obvious that the excessive quantity of organic matter contained in these liquids must be derived from organic matter *extraneous* to the clean material comprising the bed-flocks, and is not derived from the intrinsic organic matter of the same.

Bed I., before rinsing, contained 22,100,000 micro-organisms per gram of flock, *after* being rinsed, dried and teased the bacterial content per gram had increased to 131,000,000, the result of the moisture and warmth to which it had been exposed. Comparisons instituted with a specimen of white, clean cotton flock showed but 165,000 bacteria per gram in the latter, though in every specimen examined bacteriologically by Dr. Buchanan, a large number of the micro-organisms were, he writes, "probably of the same species as are found in the human intestine (Bacilli of *lactis aerogenes* and *acidi lactici* type)."

Mr. Fyfe mentions by way of comparison, in another paper he wrote on the subject, that, when the washing of flock samples showed 4,500,000 bacteria, the average number of bacteria in the same quantity of Loch Katrine water for the year 1903 was 75, and that the average of 32 examinations of Glasgow crude sewage showed no more than 197,500.

A further series of experiments was carried on by Mr. Peter Fyfe and Dr. Buchanan to find the effect upon the atmosphere of a house of the ordinary domestic process of making such beds. By the use of agar culture plates 9½ ins. square, it was found that the number of bacteria in the air was increased from 20 to 230 times in different experiments, while the atmosphere was rendered disagreeable, fusty and dusty.

(*D*) *The Removal of Dust.*

(1) Divide a square metre (39 inches) of butter muslin into three portions, (*a*), (*b*) and (*c*). Leave (*a*) dry, moisten (*b*) with a little water and sprinkle a few drops of kerosene on (*c*), sufficient to render it very slightly "greasy."

(2) Examine the furniture and fittings of the room for any evidence of dust.

Proceed to remove it from any exposed surfaces by means of (*a*) with the assistance of a feather brush. After two hours repeat your examination. To what extent has the dust disappeared ?

(3) Repeat the dusting process but use (*b*) for all china, marble, woollen, silk or cotton surfaces, and employ (*c*) for polished wood, metals, etc.

Compare the appearance of (*b*) and (*c*) with (*a*) ; which portion of muslin gives most evidence of having removed dust from the furniture, etc., to which it has been applied ?

Again examine the contents of the room after a considerable interval. Which method of dust removal is obviously the more efficacious ?

NOTE.—It is, of course, important that the room should be left under similar conditions during each interval.

As a rule, dust is merely flicked from one part of a room to another by the use of dry dusters and feather brooms, so that little, if any, is really removed. When moist and oiled cloths are used the same advantages result which are associated with the old fashion of sprinkling carpets with clean tea-leaves, damp paper, newly mown grass or other substances, to which the dust which is raised by sweeping can adhere and be removed and burnt.

Demonstrations on a rug with a broom, repeated with a Bissell carpet-sweeper will illustrate the great advantages of the latter is respect of actual dust removal. Rooms should in all cases be swept fully two hours before they are dusted in order to allow the dust time to settle, otherwise very little gain is derived from the misnamed cleansing process. Insist, too, on the importance of wide-open windows during the cleansing of a room ; an exit is thus afforded for dust, and also for the many volatile gaseous substances which are the product of domestic life, such as cooking and human occupation.

A combination of chemical, physical and mechanical action is required for most cleansing processes ; the dirt entangled in, or adherent to, the substance must be set free by a suitable solvent, then it must be removed by friction or by some other mechanical action, such as beating, shaking or brushing, while no damage must be incidentally sustained by the object cleansed. The pupils will be alive to the fact

also that dust consists rarely of dry inorganic matter ("*Cleanliness*," V., (*B*) VI., *pp.* 549-57). It is usually closely incorporated with sugary or greasy constituents and is liable to contain moulds and bacteria, which must not be allowed to germinate.

The sugary elements yield readily enough to hot water, but the fatty ones must be converted into a soap or into an emulsion, by combination with an alkali or with some form of soap or alcohol. Acids must be neutralized by alkalies; insoluble chemical salts, such as are formed by the action of certain articles of food upon cooking utensils or table silver, must be rendered soluble; metals must be protected from oxidation by being well dried or covered with a film of grease; while organic dirt and all other unpreventable impurities must be constantly and systematically removed. The observations made in IV. (*B*) will have drawn attention to another important point in cleanliness, *viz.*, that in some substances dust and grease remain upon the surface, whereas in others they penetrate every fibre of the material; diverse conditions which materially affect the cleansing methods employed and the risks of damage to the substances themselves in the process.

(*E*) *Flies as Sources of Dirt and of Infection.*

Imprison several house-flies in a large bottle, of which the mouth must be immediately covered with muslin.

Prepare two or three Petrie dishes, pour in sufficient nutrient gelatine to cover the bottom of each dish, and place them under a wire dish-cover.

Introduce the neck of the bottle under one end of the cover. Uncover the mouth and liberate the flies. Watch their movements. So soon as they have crawled over the surface of the gelatine, cover the dishes, and remove them to a warm, dark place.

Examine the appearance of the gelatine after 24 hours, and thereafter daily, for any indications of micro-organic life.

NOTE.—One source of the spread of putrefactive organisms, and of the bacilli of different forms of infectious disease (typhoid fever, infantile diarrhœa, etc.), is attributed to the common house-fly. The insects come in contact with filth of many kinds

find an entrance into dwelling-houses, and contaminate the food, and settle on the faces, etc., of the inmates. On microscopical examination, the colonies which develop on the surface of suitable nutrient media will generally show the growth of micro-organisms associated with the presence of sewage and decomposing animal matter, if not of actual pathogenic bacilli.

Flies breed every fortnight in hot weather, and lay about 120 eggs each time. In spite of their numerous enemies, flies can multiply with inconceivable rapidity, where the storage of warm, damp collections of filth offer ideal breeding-places.

The rapid and complete removal of house and farm refuse, and rigorous cleanliness in the house are indispensable for restricting the presence of these house pests.

V.—Elements of the Chemistry of Cleaning.

MATERIALS: *White vinegar; lemon; borax; milk; gooseberries or rhubarb; cream of tartar; soap; washing soda; Hudson's soap; whitening; alum; bi-carbonate of soda; caustic soda; ammonia; copper oxide; benzine; paraffin lamp-oil; hydrochloric acid; sulphuric acid; neutral litmus paper; butter muslin; cloth; silk neck tie or collar; white filter or blotting paper; fine flannel; distilled water.*

APPARATUS: *Beakers; c.c. measure; pipette; porcelain basins; bowls; wooden spoon or ruler; forceps; sand-bath; retort stand; tripod; Bunsen burner.*

(*A*) Make a study of the characteristics of Acids, Alkalies, and Salts, *see* "PERSONAL HYGIENE," VIII. (*E*), *pp.* 517-18.

(1) Take some white vinegar, and examine it as to

(*a*) Taste,
(*b*) Smell,
(*c*) Reaction to neutral litmus paper,
(*d*) Result when a few drops are allowed to fall on some bi-carbonate of soda.

(2) Make a dilute solution of hydrochloric acid by adding 1 c.c. of acid to 100 c.c. distilled water.

Repeat the tests in (1).

(3) Take 1 gram (about ½ teaspoonful) of bi-carbonate of soda and dissolve it in 100 c.c. of distilled water.

Repeat the examination as directed in (1) but substitute 2 c.c. of hydrochloric acid for the bi-carbonate of soda used in (*d*).

(4) Make a solution of ammonia in the proportions directed in (2). Repeat the tests given in (1).

(5) Apply similar tests to the following substances and classify them as acids and alkalies in the light of the observations made in (1), (2), (3), (4).

Lemon juice, borax, milk, the juice of gooseberries or rhubarb, cream of tartar, soap, washing soda, Hudson's soap, whitening and alum.

(6) Place a few c.c.'s of the solution of hydrochloric acid used in (2) in a small beaker (*a*).

Make a weak solution of caustic soda by dissolving a small piece in 100 c.c. of water (*b*).

CAUTION.—Do not handle wet caustic soda with the fingers, forceps must be used or the strong alkali may cause a painful burn (*see* "*Personal Hygiene*," VIII. (*E*), *pages* 517-18).

Fill a pipette with (*b*) and add cautiously to (*a*) until neutral litmus paper becomes neither blue nor red, but remains violet when drops of the fluid are allowed to fall upon it.

Taste the solution.

The neutralization of the acid with an alkali has resulted in the formation of a salt (chloride of sodium or common salt). Evaporate the solution in a porcelain basin over a sand-bath heated by a Bunsen flame.

Examine the residue by touch and taste, it is common table salt.

NOTE.—All acids resemble each other in the following respects:—usually they have a sour taste, they turn blue or neutral litmus paper or solution red, they effervesce or cause the evolution of carbon dioxide gas from carbonates such as soda or chalk, and they unite with various substances, described as bases, to form compounds which differ entirely from both

the acid and the base of which they are the product. These new substances also possess certain resemblances one to another, more especially in their tastes, indeed they are called "salts" because the commonest among them is chloride of sodium. Bases, however, are not necessarily alkalies; the oxides of metals, for instance, are bases, though they are not alkalies.

To illustrate this fact, it will be well for the pupils to perform the following experiment:—

Place 12 or 15 c.c. ($\frac{1}{2}$ oz.) dilute sulphuric acid in a porcelain basin, arranged on a sand-bath over a Bunsen flame, and raise to boiling point. Drop in small quantities of copper oxide, so long as they dissolve on boiling.

When the oxide no longer dissolves, pour off the liquid into a second porcelain basin and evaporate it slowly on a hot sand-bath.

The crystals which appear are composed of sulphate of copper; that is the base, copper oxide, has combined with the sulphuric acid to yield a salt, described as copper sulphate.

"Soap, chemically considered, is a salt, made up of a fatty acid and the metallic substance sodium. The fatty acid can be separated by adding any acid, like vinegar, to a solution of soap. If the solution be warm, it rises as a scum to the top. It can be dissolved in ammonia, forming an ammonia soap. The sodium part of the soap unites with the acid and forms a salt. If hydrochloric acid is added to a soap solution (a sufficient quantity to make the solution very slightly acid), the fatty acid removed, and the residue evaporated to dryness, common salt will be found. If lime water be added to a solution of soap, white clots of "lime soap" will be formed which are insoluble in water, but on collecting and drying will be found to dissolve in gasoline, naphtha, or kerosene. This is why naphtha or gasoline is useful in cleansing bath-tubs, bowls, etc. Quite a good varnish can be made of aluminium soap, made from alum and white soap, dried and dissolved in gasoline." *("Chemistry of the Household," Dodd. American School of Home Economics.)*

Alkalies resemble each other in the fact that they turn red or neutral litmus paper or solution blue, and that they yield a soapy sensation when the fingers are rubbed together after dipping in an alkaline solution.

Alkalies are described as "strong bases" as compared with others such as oxide of copper or oxide of iron. Caustic potash and caustic soda are the most familiar examples. Skilfully employed with hot water, alkalies are valuable solvents for dirt, especially when of a sooty or greasy nature, but only dilute solutions should be used for washing painted woodwork, carpets, linen, etc., or the paint, polish, varnish, or fabric will be removed or injured by their corrosive action.

Ammonia cannot remove tarnish caused by a combination of sulphur with silver from metallic surfaces unless used in a form so potent as to injure the articles themselves. But if such tarnished articles are rubbed before washing with common salt, a salt, chloride of silver, is formed which is freely soluble in a solution of ammonia.

Common sources of sulphur acids or sulphur are found in the combustion of coal or gas, wrapping paper, or white flannel, rubber in any form, and eggs. Other forms of tarnish on metals are caused by moisture (which always favours chemical changes), by the oxygen in the air, by gases from manufacturing products or from sewers and drains, and by many acids, organic and inorganic. Acids are useful to remove obstinate rust or ink-spots, and to clean the stains which form on china if the water supply is strongly impregnated with iron. When applied to fabrics, the material should be subsequently washed with an alkaline solution to neutralize the otherwise corrosive effects of an acid.

(*B*) *Solvents.*

(1) *Hot Water.*

Prepare two bowls (*a*) and (*b*). Fill—

(*a*) With boiling water;
(*b*) With tepid water.

Slightly grease two plates and sprinkle with crumbs, immerse one in (*a*), the other in (*b*), for 3 or 4 minutes, rubbing each with a piece of butter muslin. (For (*a*) the muslin should be made into a mop by tying to a wooden spoon or ruler, for the water must be too hot for the hands to bear).

Compare the appearance of the two plates upon removal, stand on edge to drain for 5 minutes.

Observe that (*a*) is dry, clean and bright, while (*b*) will be wet, greasy and smeared.

NOTE.—Boiling water melts off and carries away grease, and evaporates rapidly from non-absorbent surfaces, it is effective as a cleanser and economical of labour.

(2) *Soap*.

Repeat XXIII. "CLEANLINESS," I. (*B*) (*C*), *pp*. 544-5.

NOTE.—Soaps decompose slightly when dissolved in water and form emulsions with greasy matters in which dirt is entangled, so that dirt, soap and grease are all washed away together. An excess of alkali in a soap, though increasing its cleansing effect, will damage both skin and fabrics by its corrosive action.

(3) *Chemical Solvents*.

CAUTION.—These are often highly inflammable and must never be used near a light or fire.

Mix 2 c.c. of paraffin lamp-oil with 250 c.c. of hot water, dip a cloth in the mixture and apply it to the piece of leather stained with dirty water in IV. (*B*), rub well and wipe dry with a clean, soft cloth.

Take a small piece of soiled silk such as a neck-tie or collar, stretch it over a pad of white filter or blotting paper, wet a small piece of fine, clean flannel with benzine, and gently rub the soiled part of the article, constantly shift the pad beneath in order to present a fresh surface to absorb the grease dissolved by the benzine.

Repeat until the piece of silk is quite clean.

NOTE.—Paraffin lamp-oil, petroleum, benzine, chloroform and turpentine are all admirable solvents of dirt and grease when intelligently employed; a few drops of the selected solvent are added to hot water as a rule, because the water acts as a carrier over a large surface; the paraffin, petroleum, etc., do not dissolve in the water as is occasionally erroneously assumed.

For carpets or furniture, therefore, a small quantity of the solvent should be added to hot water, and the articles to which it is applied should be rinsed or sponged afterwards with tepid water and then rubbed dry with a soft cloth. For all polished wood, leather surfaces, or painted wood-work a few drops of paraffin or turpentine may be used by merely dropping them on to a soft cloth.

Paraffin is less inflammable than turpentine but requires harder rubbing, as it evaporates slowly and unless thoroughly removed the surface remains sticky, so that dust adheres freely.

Turpentine cleans more thoroughly, but, like benzine, is very highly inflammable, while it evaporates very rapidly. It owes its value as a detergent to its solvent power on grease and resinous matter, not to any strictly chemical action.

In the case of both paraffin and turpentine, their extensive use as cleansing agents is due almost entirely to their physical property of a low surface tension, that is, their molecules have very little attraction for each other, and so these liquids very readily spread themselves over any surfaces with which they come in contact. Paraffin, for instance, spreads over everything and into every cranny, as all users of paraffin lamps know to their cost. It is to this "creeping" property, or the fact that other surfaces attract it more than it attracts itself, that this oil owes its value where vegetable oils are useless. Powders such as emery, pumice, fine sand, whitening and French chalk (magnesia) are useful to increase the mechanical effects of some cleansing processes. They are usually mixed with water, oil, or a weak alkali, and are used to scour stone, metal, marble, or to remove rust from metallic surfaces. Their action may be compared to that of a fine file, which grinds away the surface to which it is applied.

(4) *The use of Dry Powders as Cleansing Agents.*

Smear the tip of one finger with a greasy substance (butter, oil, etc.), and lightly press it for a few seconds on to a piece of silk or thin dress material.

Dust some fuller's earth instantly and thickly over the stain, and leave it in position for 24 hours.

Examine the appearance of the powder before shaking or brushing it off, and then observe to what degree the grease upon the fabric has been absorbed. How is this result to be explained?

NOTE.—Fuller's earth may be regarded as a kind of blotting powder. Being a powder, it necessarily represents a large surface in a small bulk. Its power of absorbing grease is again a phenomenon of surface tension.

Dignity of Household Science.

NOTE.—The few suggestions contained in the section on Domestic Cleanliness are intended merely to indicate lines which it is hoped that teachers will very generally develop in the course of elementary science teaching.

It is of special importance, under modern conditions of existence, to direct the attention of young people to the opportunities which present themselves in daily domestic life for the employment of knowledge gained in school studies, as well as for the application of scientific principles to the betterment of health and to lightening the drudgery of unintelligent labour, which has been guided in the past almost solely by rule of thumb methods. The question of domestic cleanliness is at once hygienic and economic.

"To rightly clean right objects," it has been said, "is noble work." If the presence of effete matter in the body invites disease, most certainly it does when present in the house; to remove it systematically represents persevering effort, but this can be much promoted if modern knowledge be called in to assist.

Sanitation is the summary of cleanliness, but such cleanliness can only be practised intelligently when based on a sound knowledge of the laws by which its methods are governed, and by the aid of labour-saving appliances now to be obtained.

Pupils should be invited to observe and report upon the applications to be found in every house of the elementary principles of mechanics for the facilitation or reduction of labour. They are employed, for example, in the transmission of force by means of wheels in sewing, wringing or mangling machines, or by the recoil of springs. Further familiar illustrations are offered by the employment of spheres in a confined space (ball bearings) to minimize friction, or the exercise of firmness, tenacity and steadiness by the use of the screw.

In conclusion, the close interconnection between Domestic and Municipal Sanitation should be traced, so that the place of a practical knowledge of Hygiene in the equipment for life of both boys and girls may be appreciated, and a real desire to practise its precepts may be stimulated.

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SHORT GLOSSARY.

Abdo′-men, the belly, containing the principal digestive and excretory organs (L. *abdo*, to hide).

Abduc′-tion, the action by which muscles separate certain parts of the body from others with which they are conjoined, as when the arm is carried from the side towards the extended position. (L *abduco*, to lead away).

Acetab′-ulum, the cup-shaped cavity of the hip bone which receives the head of the thigh bone (L. *acetabulum*, a cup-shaped vessel, originally for *acetum*, vinegar).

Adduc′-tion, the drawing together of one part of the frame to another by muscular action, as when the arm is brought to the side from an extended position (L. *adduco*, to lead to).

Aëro′-bic, applied to those forms of bacteria which cannot live in the absence of air — which demand oxygen for their existence (Gr. *aēr*, air; *bios*, life).

Albu′-minoids, *see* Proteids.

Albu′-mins, a class of proteins, soluble in water and dilute salt solutions, coagulated by heat; the white of an egg consists essentially of egg-albumin; serum-albumin is found in blood and lact-albumin in milk (L. *albus*, white).

Aliment′-ary Canal, the whole channel or passage through the body for receiving and digesting food and rejecting excrementitious matter (L. *alimentum*, nourishment).

Amphoter′-ic, partly the one and partly the other; exhibiting both acid and alkaline characteristics (Gr. *amphoteros*, comparative of *ampho*, both).

Amylolyt′-ic; an amylolytic ferment is one which brings about the conversion of starch into the soluble form, or converts it into sugar (*e.g.*, diastase, ptyalin) (Gr. *amylon*, starch; *lysis*, solution).

Anab′-olism, a process by which a substance is transformed into another more complex and more highly organized, as the conversion of the nutritive elements of food into tissue. *See* "Metabolism." (Gr. *anabolē*, a throwing-up).

Anaërob′-ic, applied to bacteria which live without oxygen. The products of putrefaction produced by these bacteria are usually more poisonous than are those of aërobic bacteria (Gr. *an*, negation; *aēr*, air; *bios*, life).

Ar′-ris, the sharp edge or salient angle formed by two surfaces meeting each other, whether plane or curved; applied particularly in architecture (Fr. *arête*, from L. *arista*, the bone of a fish; the top or beard of an ear of corn).

Astig′-matism, a defect in eyesight, arising from a structural error in the curvature of the cornea, or more rarely of that of the lens. For such cases, a luminous point will not appear as a point, but will put on some other appearance, dependent on the nature of the malformation (Gr. *a*, priv; *stigmatizo*, to prick, any mark or spot).

Atherom′-atous, curdy in appearance or consistency (Gr. *atharē*, groats or meal).

Au′-ricle, one of the chambers of the heart into which the blood comes from the veins; so called on account of its ear shape (L. *auricula*, little ear).

Bacil′-lus, a sub-division of the lower bacteria group, characterized by rod-like forms. They *multiply* by fission and *reproduce* by spores (L. *bacillum*, a little staff).

Bactē′-ria, a genus of microscopic fungi characterized by short, linear, rod-like forms, without tendency to unite into chains or threads; they are allied to yeasts and moulds, and multiply by division or fission; some forms reproduce by spores (Gr. *baktēria*, a staff or cane).

Bī′-ceps, a muscle having two heads or origins (*see* cut, *page* 156), and lying between the shoulder and elbow in front of the arm (L. *bis*, twice; *caput*, head).

Cal′-orie, a unit of heat, *viz.*, the amount of heat required to raise the temperature of 1 gram of water 1° C. (L. *calor*, heat).

Calorim′-eter, an instrument for determining the amount of heat given out by a body under various conditions. It is constructed in varied forms, a common type being simply a polished copper vessel containing a known weight of water, the heat evolved being measured by the rise in temperature of the water (L. *calor*, heat; Gr. *metron*, measure).

Car′-thus, a cavity at the extremities of the eyelids; the greater next to the nose, the lesser near the temple (Gr. *karthos*, a corner).

Car′-tilage, a tough elastic substance, softer than bone; gristle (L. *cartilago*, gristle).

Ca′-sein, *see* "Caseinogen."

Casein′-ogen. It has recently (1907) been suggested that this term should be used for the principal protein in milk, and casein for its derivative, which is the result of the action of rennet (L. *caseus*, cheese; Gr. *gennao*, produce).

Cauda equina, the bundle of nerves in which the spinal chord terminates; so called from their great length and the appearance their roots present (L. mare's tail).

Chias′-ma, a crossing of two portions of the optic nerve, so called from its resemblance to the junction of lines in the Greek letter χ (*chi*).

Chlor′-ophyll, the green colouring matter of plants which, under the influence of sunlight, is capable of decomposing the carbon dioxide of the air, liberating the oxygen, and retaining the carbon for the use of the plant (Gr. *chloros*, green; *phyllon*, leaf).

Circumduc′-tion, the moving of a limb around an imaginary axis in such a manner that it describes a conical figure (L. *circumduco*, to lead round).

Coag′-ulum, a coagulated or concreted mass, as the curd of milk: a blood clot (L. *coagulo*, to coagulate).

Coapta′-tion, a form of angular movement, in which the articular surface of one bone travels over that of another so as to bring different parts of the surface successively into contact, in the manner of a wheel rolling on the ground (L. *coapto*, to fit or join together).

Coc′-cus, a spherical or nearly spherical cell-form of lower bacteria. The sub-divisions of the cocci depend upon the relation of the individual elements to each other. A simple round cell is called a *micro-coccus*, a combination of cocci in pairs is termed *diplo-coccus*, a combination of a number into a twisted chain is described as *strepto-coccus*; the fourth form, when the micro-cocci are massed like bunches of grapes is called *staphylo-coccus* (Gr. *kokkos*, a berry).

Cotyle′-don, the seed-leaf, or the first leaf or leaves of the embryo plant, present as the embryo of every seed capable of germination, containing a greater or less supply

of food for the use of the germinating plant (Gr. *kotyle*, a cup).

CRI'-COID CARTILAGE, the more or less modified and specialized first ring or cartilage of the wind-pipe; in man it is expanded behind, and resembles a signet ring (Gr. *krikos*, a ring; *eidos*, form).

DEGLUTIT'-ION, the act of swallowing (L. *de*, down; *glutio*, to swallow).

DE'-HYDRATE, to deprive of water (L. *de*, not; Gr. *hydor*, water).

DEL'-TOID MUSCLE, the large triangular-shaped muscle of the shoulder, covering and protecting the joint. Its action raises the arm away from the side of the body (Gr. *delta*, the letter Δ; *eidos*, form).

DES'-ICCATE, to dry up or exhaust of moisture (L. *desicco*, to dry up).

DI'-ALYSER, an instrument for exhibiting osmosis may well be a dialyser, but if it is used for measuring osmosis or osmotic pressure, it should be called an Osmometer.

A dialyser is essentially a tambourine floating in a basin of water, used for separation of crystalloids or colloids; an osmometer (commonly, but inaccurately often described as a dialyser) exhibits or measures a difference of pressure. In each case the *motion* is osmosis (Gr. *dia*, apart; *lyo*, to loose).

DIAL'-YSIS (*see page* 24), the operation of separating solutions of mixed substances of an unequal diffusability (as crystalloids and colloids), by taking advantage of their different capacities for passing through moist membranes or septa (the crystalloids passing through freely and the colloids slowly, or not at all) (Gr. *dialyō*, from *dia*, apart; *lyō*, to separate, to loose).

DI'-ASTASE, an enzyme or ferment existing in germinated grain, soluble in water and dilute alcohol, and capable of breaking up starch into dextrine and glucose (Gr. *diastasis*, separation).

DUODE'-NUM, the first portion of the small intestine, immediately connected with the stomach; so called because in man it is about twelve finger-breadths long (L. *duodeni*, twelve each).

EM'-BRYO, the rudiments of the future plant, contained in all true seeds, not in spores; the first beginning of the animal development, not born, and still undeveloped (Gr. *embryon*, from; *en* (*em*), in; *bryō*, to swell).

EMUL'-SION, finely divided matter suspended in a colloid body; or water or other liquid in which oil in minute subdivision of its particles, is suspended (L. *emulgeo*, to milk out, to drain).

EN'-DOLYMPH, the limpid fluid contained in the membranous labyrinth of the middle ear (Gr. *endon*, within; + lymph).

EN'-DOSPERM, the name given to the food-supply stored in a seed for the nutrition of the embryo plant. These reserve materials may be in the form of starch, fat, or proteids. When the embryo begins to grow, chemical changes take place in these materials so that they are converted into forms which can readily travel to the growing parts of the young plant (Gr. *endon*, within; *sperma*, a seed).

EN'-ZYME, an unorganized ferment (*e.g.*, diastase, pepsin), capable, under favourable conditions, of inducing chemical changes in enormously large quantities of substances without itself necessarily undergoing change (Gr. *en*, in; *zume*, leaven).

EUSTA'-CHIAN TUBE, a small duct running from the middle-ear into the back part of the mouth (*Eustachio*, an Italian anatomist, died 1574).

FASC′-IA, a thin tendon-like covering surrounding muscles and binding them in their places (L. a sash, a band, a fillet).

FOR′-MALIN, the name given to an aqueous solution of *formaldehyde*; a strength commonly used is 40 per cent., and such a solution is a powerful antiseptic and preservative for food [Formaldehyde (CH_2O) is a colourless gas obtained variously by the partial oxidation of methyl alcohol].

GAN′-GLION (*pl.* ganglia), a separate and semi-independent nervous centre, communicating with other ganglia or nerves, and with the central nervous system, and peripheral organs (Gr. *ganglion*, a tumour near a tendon).

GASTRO-CNE′-MIUS, a superficial muscle of the leg (*see Fig.* 39, *page* 157), the action of which extends the foot upon the leg and bends the leg upon the thigh; so called because it forms part of the "bellying" or protuberant portion of the calf of the leg (Gr. *gaster*, stomach; *kneme*, leg).

GERM (1) The earliest stage in the existence of an organized being; (2) The generic term applied to micro-organisms, and popularly to those specific organisms associated with diseases of an infectious character (L. *germen*, a young shoot, a sprout).

GERMINA′-TION, the first act of growth which takes place in an embryo plant. It cannot occur without the presence of water, heat (20° to 30° C.; 68° to 86° F.) and oxygen. The cells of the embryo become distended and turgid, the seed-coat ruptures and the radicle or primary root grows downward into the soil (L. *germino*, to bud, to sprout).

GLY′-COGEN, also called animal starch, is a body of the carbohydrate class found in many animal tissues, and especially in the liver; it appears to be a reserve material which is converted as required into sugar (Gr. *glykys*, sweet; *gennao*, to produce).

HYDRA′-TION, the act of moistening or impregnating with water; the state of being moistened (Gr. *hydōr*, water).

HYDROLY′-SIS, a kind of chemical decomposition by which a compound is converted into other compounds by taking up the elements of water (Gr. *hydor*, water; *lysis* (*lyein*), to lose).

HYGROM′-ETER, an instrument for measuring the comparative moisture of the air. There are three kinds: (1) those which act by absorption; (2) by condensation; and (3) those in which the hygrometric condition is deduced from observations of a wet and dry bulb (Gr. *hygros*, wet; *metron*, measure).

HYPERMETRO′-PIA, long sight; eye too short. Rays of light are focussed behind the retina, but can be brought to a focus on the retina by the use of a convex lens (Gr. *hyper*, above, beyond).

IMPETI′-GO, a skin eruption usually consisting of clusters of small yellow-scaled pustules (L. *impeto*, to attack).

INTERCOST′-AL MUSCLES, two sets of muscles whose fibres cross each other obliquely, and connect the adjacent margins of the ribs (L. *inter*, between; *costa*, a rib).

IN′-VERTASE, a ferment present in yeast, which is capable of converting cane-sugar into "invert" sugar, the latter being then able to undergo alcoholic fermentation. The name is associated with the fact that after the action of the ferment, the optical properties of the sugar solution are reversed or "inverted."

ISOM′-ERIDES, chemical substances which have the same molecular formula, yet different properties

are said to be *isomeric*, and the substances themselves are called *isomers* or *isomerides*. Isomerism is explained by assuming a difference in the arrangement of the atoms in the molecule (Gr. *isos*, equal; *meros*, a part).

JEJU′-NUM, the second division of the small intestine situated between the *duodenum* (*q.v.*) and the *ileum*: so named because it was supposed to be empty after death (L. *jejunus*, hungry).

KATAB′-OLISM, *see* "Metabolism."

KILO-CALORIE, the amount of heat required to raise 1 kilogram (about 1¾ pints) of water 1° C., or 1 lb. water 4° F. It is written with a large C. (*see* Calorie) (Gr. *chilioi*, a thousand; L. *calor*, heat).

KINET′-IC, putting in motion; imparting motion (Gr. *kineo*, to move).

LACH′-RYMAL, generating or conveying tears (L. *lacrima*, a tear).

LACTALBU′-MIN, the particular form of albumin which is found in milk (L. *lac*, milk; *albumen*, from *albus*, white).

LACTOM′-ETER, a specialized form of *hydrometer*, used for finding the density of milk, by noting to what mark on the stem the instrument is immersed when allowed to float freely in the liquid (L. *lac*, milk; Gr. *metron*, measure).

LAM′-INA, a thin coat or layer lying over another (L. *lamina*, a leaf, a layer).

METAB′-OLISM, the sum of the chemical changes within the body, or within any single cell of the body by which the protoplasm is either renewed, or changed to perform special functions (constructive metabolism or anabolism) or else disorganized and prepared for excretion (destructive metabolism or katabolism) (Gr. *metabole*, change).

METHYL VIOLET, an organic dye, often used as an indicator of the presence of free acids, since with these it gives a green colour.

MI′CRO MI′CRON, the one-thousandth part of a *micron*, which is itself the one-millionth part of a metre.

A micron is usually represented by the sign 1 μ, and a micromicron (or micro-millimetre as it also is called) by 1 $\mu\mu$.

Another small unit, often used in recording the measurements of the wave-lengths of light, is known as a "tenth-metre" (10^{-10} metre) 1 $\mu\mu$ = 10 tenth-metres (Gr. *mikros*, small, minute).

MI′-CROPYLE, In botany, the minute hole at one end of the *hilum* (*e.g.*, the black scar on a bean seed), through which moisture is absorbed or from which it exudes under pressure (Gr. *mikros*, small, little, *pulē*, an opening; the little gate).

MOL′-ECULE, the smallest quantity of an element or a compound which is capable of separate existence, or which can exist in a free or uncombined state (L. diminutive of *moles*, a mass).

MU′-CIN, a nitrogenous body of protein nature, found in connective tissue; it is a glutinous substance soluble in weak alkalis, but not in water (L. *mucus*, the slimy fluid from the nose).

MYO′-PIA, near sight, a condition when, by reason of length of the eyeball or increased refractive changes in the media, rays of light from a distance are focussed in front of the retina, producing an indistinct image. This can be remedied by the use of a concave lens (Gr. *muōps*, to shut).

NESS′-LER GLASS, a tall, narrow glass cylinder, of varying capacity, but holding usually 50 or 100 cubic centimetres, and used in the estimation of ammonia in water by a colorimetric method. It is also applicable in other cases where it is required to match the colour possessed by a column of liquid.

NITRIFICA′-TION, the purification of sewage or other organic matter through the agency of bacterial organisms which exist in the upper layer of soils. "Nitrifying organisms feed on the organic matter causing its oxidation. The soil or sewage must be rich in lime or other alkali, for the nitric and nitrous acids formed by the nitrifying organisms must be able to combine with bases, or the nitrifying action ceases."—*Parkes and Kenwood* (L. *nitrum*, nitre; *facio*, to make or do).

ŒDE′-MA, a minor form of dropsy, consisting of puffiness of a part arising from the collection of fluid under the skin (Gr. *oidēma*, a swelling).

OESOPH′-AGUS, the gullet or tube leading from the mouth to the stomach, and through which food is carried (Gr. *oiso*, future of *phero*, to carry; and *phago*, to eat).

OSMO′-SIS, *see page* 24 and under Dialysis (Gr. *osmos*, pushing).

PAN′-CREATIN, the active principle of the pancreatic juice (*i.e.*, the special secretion of the pancreas or sweet-bread), which in alkaline solution is capable of decomposing proteins, fats, and starch (Gr. *pan*, all; *kreas*, flesh).

PAROT′-ID GLAND, in man, the largest of the three pairs of salivary glands; it is situated near the ear and secretes saliva, which is poured into the mouth by a special duct (Gr. *para*, beside; *ous* (*otos*), ear).

PEC′-TOSE, a substance contained in fleshy fruits, roots, etc., insoluble in water, but under the influence of certain reagents, is transformed into soluble pectin, the body which imparts to the juice of fruits the property of gelatinizing when boiled (Gr. *pektos*, congealed).

PEP′-SIN, a ferment found in the gastric juice which in the presence of weak acids is capable of converting proteins into peptones. The name is also applied to a substance procured by scraping the mucous lining of the stomach of some animal (usually the pig, sheep, or calf), and drying the viscid pulp thus obtained (Gr. *pepto*, to cook, digest).

PEP′-TONES, a class of proteins into which the nitrogenous elements of food are converted by the action of the gastric or pancreatic juice. The peptones are soluble in water, and are not coagulated by heat (Gr. *pepto*, to cook, digest).

PERISTAL′-TIC, pertaining to peristalsis, a peculiar involuntary muscular movement, consisting of circular contractions travelling along in a wave-like form; best seen in the intestines, their contents being thus propelled onward (Gr. *peri*, around; *stellein*, to send)

PE′-TRIE DISHES, these consist of two flat glass dishes, the larger of which can be inverted and serves as a cover for the other; they are used in bacteriological work for preparing plate cultures.

PHAR′-YNX, the cleft or cavity forming the upper part of the gullet (Gr. *pharyngks*, throat).

PIA MATER, a vascular membrane, containing numerous lymphatic vessels, which closely invests the brain and spinal cord: it is fibrous and of extreme delicacy (L.).

PLEX′-US, a network of vessels, fibres, or nerves; *e.g.*, when nerves in their courses, subdivide into branches and communicate with branches of a neighbouring nerve, such a communication is called a *plexus* (L. *plexus*, a fold, a plait).

PLU′-MULE, the bud of the ascending axis of a plant while still in the embryo (L. *plumula*, a little feather).

PNEUMOGAS′-TRIC NERVE, the longest and most widely distributed of the nerves of the brain, extending through the neck to the upper

part of the abdomen (Gr. *pneumon*, lung; *gaster*, stomach).

Pro′-teids, the class name given to a group of nitrogenous organic substances which make up the substance of the tissues of the body, and of the blood, and are also widely distributed in the vegetable kingdom. They include such bodies as *albumen*, *gluten*, *casein*, etc., and are often called *albuminoids* (*see* "Protein") (Gr. *proteion*, pre-eminence).

Pro′-tein, *see* "Proteids." The general name for a group of complex nitrogenous compounds of which albumen is the most familiar example. It is now (1907) recommended that the term "proteid" be abolished and "protein" substituted as the general class name.

Pro′-toplasm, defined by Huxley as "the physical basis of life"; "living matter which acts in virtue of its peculiar organisation," of which Prof. Thomson says only a hypothetical conception can be formed.

"It is an albuminous substance, ordinarily resembling the white of an egg, consisting of carbon, oxygen, nitrogen, and hydrogen, in extremely complex and unstable molecular combinations, and capable, under proper conditions, of manifesting certain vital phenomena, such as spontaneous motion, sensation, assimilation, and reproduction." *Colton* (Gr. *protos*, first; *plasma*, to mould, to form).

Pto′-maines, *i.e.*, cadaveric substances. The products of the action of certain bacteria upon albuminous substances. These micro-organisms break up complex organic matters into less complex compounds. Ptomaines, which are organic bases, are formed at different stages of the process of decomposition; some are poisonous, but others are wholly inert (Gr. *ptōma*, a corpse).

Sap′-rophytes, those species of bacteria which feed upon non-living material, and are incapable of leading a parasitic life. The majority are harmless, and most of them are beneficial (Gr. *sapros*, rotten; *phagein*, to eat; to live on decayed matters).

Sarto′-rius, the longest muscle of the human body, crossing the thigh obliquely in front; supposed to be the chief muscle in producing the position of the tailor when at work, whence the name (L. *sartor*, a tailor).

Seba′-ceous Gland, a gland of small size, usually opening into a hair-follicle, and secreting an oily substance, which lubricates the hair and skin (L. *sebum*, tallow).

Spic′-ule, a needle-shaped particle (L. *spica*, an ear of corn).

Symbio′-sis, the living together of two organisms under conditions which are beneficial to each; this differs essentially from "parasitism," in which one organism preys upon the other (Gr. *syn*, together; *bios*, life).

Syno′-vial Fluid, a fluid like the white of an egg, which lubricates the joints and facilitates their movements; it is secreted by a membrane which lines the joints (Gr. *syn*, together; L. *ovum*, egg).

Testa, the integument or outer covering of a seed (L. a brick, a tile, a shell).

Tho′-rax, in the higher animals, the region of the body that lies between the abdomen and the head; it contains the heart and the lungs, and is enclosed by large ribs (Gr. *thorax*, breastplate).

Thy′-mus Gland, a ductless gland, situated inside the thorax, behind the breast bone, near the root of the neck; so called by Galen (born 130 A.D.) from its resemblance to the flower of *thyme*.

THY'-ROID GLAND, a large gland, consisting chiefly of blood vessels situated upon the larynx and upper part of the windpipe. It is the seat of the disease known as *goitre*, when the gland becomes sometimes very enlarged (Gr. *thyreos*, a shield; *eidos*, form).

TIB'-IA, the inner and usually the larger of the two bones of the lower leg, extending from the knee to the ankle, commonly called the shin-bone (L. *tibia*, shin-bone).

TOX'-INS, the decomposition products and secretions formed by certain bacteria when they obtain a foothold in the body; they are of a distinctly poisonous character, and cause injury of a more or less serious, permanent, or fatal nature (Gr. *toxikon*, poison).

TRACH'-EA, the chief air passage of the body, viz., the windpipe, beginning at the larynx and ending at the bronchial tubes (Gr. *tracheia*, windpipe).

U-RE'-THRA, a tube from the bladder to the exterior, through which the urine is discharged (Gr. *ouron*, urine).

VASO-MOTOR, a term applied to nerves which govern the motions of the blood vessels (L. *vas*, a vessel; *motor*, movement).

VEN'-TRICLE, one of the chambers of the heart which receives the blood from the auricles and propels it into the arteries (L. *ventriculus*, belly).

XAN'-THOPHYLL, the peculiar yellow colouring matter of autumn leaves due to the decomposition of the chlorophyll; also called "phylloxanthin" (Gr. *xanthos*, yellow; *phyllon*, leaf).

XAN'-THOPROTEIC TEST. This test (*see page* 168), is so called from the colour of the solution or precipitate produced by the action of nitric acid and heat upon bodies of a proteid nature (Gr. *xanthos*, yellow, and *protein*).

YEAST, microscopic plants (which multiply by a process called "budding"), composed of oval bodies much simpler than moulds in structure. Yeasts are the natural agents which produce the phenomenon called fermentation; they exist in three different states: (1) growing, (2) resting, (3) spore-bearing.

ADDITIONAL.

CALX, the substance of a metal or mineral which remains after being subjected to violent heat. (L. *calx*, lime).

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